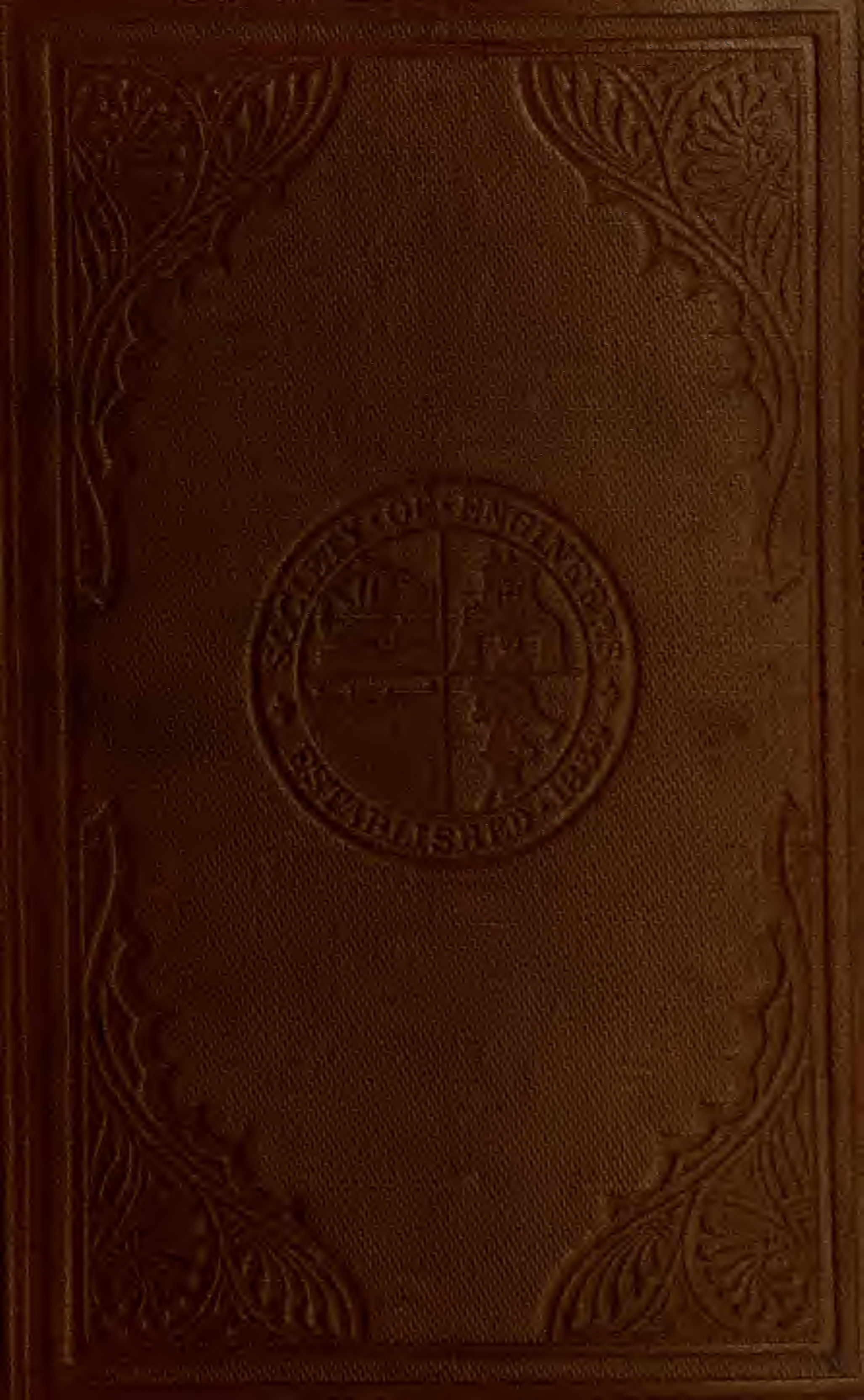
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ESTABLISHED MAY 1854

Journal and

TRANSACTIONS FOR 1901

AND

GENERAL INDEX, 1857 TO 1901

EDITED BY

PERRY F. NURSEY

SECRETARY

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PAPERS AND PREMIUMS.

The Council of the Society of Engineers invites original communications from Members and Associates, as well as from gentlemen who do not belong to the Society, on subjects connected with any branch of Engineering.

For any papers that may be considered sufficiently meritorious the Council may at discretion award one or other of the following Premiums, viz.:—

1. The President's Premium, given annually by the President, and consisting of a Gold Medal of the value of Five Guineas.

2. The Bessemer Premium, provided for annually by the late Sir Henry Bessemer, F.R.S., Honorary Member, of the value of Five Guineas.

3. The Society's Premiums, given annually by the Society, of an aggregate value not exceeding Twenty Pounds.

The number and value of the Society's Premiums are decided by the Council according to the number of meritorious papers read during the year.

By the Rules of the Society, Members of Council are disqualified from receiving Premiums for Papers.

PREMIUMS FOR 1901.

At a Meeting of the Society, held on February 3, 1902, the following Premiums were presented, viz.:—

The President's Gold Medal to:

H. Alfred Roechling, for his paper on The Sewage Question during the Last Century.

The Bessemer Premium of books to:

Roger G. Hetherington, for his paper on The Main Drainage of Ilford.

A Society's Premium of books to:

Arthur T. Allen, for his paper on Concrete Subways for Underground Pipes.

A Society's Premium of books to:

Sydney A. Hollis, for his paper on Preliminary Investigations for Water Supply.

A Society's Premium of Books to:

J. Freebairn Stow, for his paper on Irrigation Works in South Africa.

CONTENTS.

PAGE

Inaugural Address of the President, Charles Mason .. 1

Notes on certain Details of Drainage Construction. By Gerard J. G. Jensen 19

The Production of Metallic Bars and Tubes under Pressure. By Perry F. Nursey 45

The Treatment of Low-Grade Iron Ores for the Smelting Furnace. By Thomas B. Grierson 69

Concrete Subways for Underground Pipes. By A. Taylor Allen 99

Vacation Visits 137

Preliminary Investigations for Water Supply. By Sydney A. Hollis 147

Irrigation Works in South Africa. By J. Freebairn Stow .. 159

The Main Drainage of Ilford. By R. G. Hetherington .. 173

The Sewage Question during the Last Century. By H. Alfred Roechling 193

Obituary 231

Annual Report of Council and Statement of Accounts, 1901 232

Index 241

SOCIETY OF ENGINEERS.

ESTABLISHED MAY 1854.

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PLACE OF MEETING.

THE ROYAL UNITED SERVICE INSTITUTION, WHITEHALL.

1902

TRANSACTIONS, &c.

February 4th, 1901.

INAUGURAL ADDRESS.

By CHARLES MASON, President.

Gentlemen,—It is with feelings of pride, accompanied, however, with a certain amount of diffidence, that I now take the chair as your President for the year upon which we have just entered. It is a source of great gratification to me to feel that I have your confidence, and I take this opportunity—the first I have had since my election—of thanking you sincerely for having elected me to the honourable position I now occupy.

When I look back upon the long list of eminent men who have preceded me in this chair, I feel how unworthy I am to follow in their steps. This feeling, however, prompts me to throw my whole energy into the work of the Society, so that when my term of office expires I shall not feel that I have in any way given you cause to regret conferring upon me the honour of presiding over you. It is impossible for an individual or an institution to stand still, we must either go forward or backward; and I feel confident that, with the assistance of the Council and Members generally, the first year of the new century will see the Society still advancing, both with regard to our roll of membership and attendance at the meetings, as well as in respect to our financial position.

This being the first year of a new century marks an epoch in our history, and will, I trust, be an incentive to us all to make a record as to the work before us. In entering upon a new century, one naturally feels tempted to review the progress of engineering science for the past hundred years; I feel, however, that were this the principal subject of my address, too much time would be occupied in dwelling upon matters of history which are, or should be, as household words to you. The century's progress has been marvellous in every branch of science and practice, and in order to realise the enormous strides that have been made in our own profession, we have only to compare a modern express train with the stage-coach; an iron-clad with the "wooden walls of old England"; the sending of messages by wireless telegraphy with the post-boy on horseback; the motor car with the hobby-horse; the electric light with the tallow candle, and the thousands of machines of every description that were unthought of a hundred years ago. Under the circumstances, we cannot but feel that he is a bold man who would predict a similar rate of progress for the next hundred years.

It would be wrong, however, to conclude that this advance is entirely due to the intellect and skill of the past century, as all inventions and improvements are to be attributed to a development of ideas formed long before, upon which we have been able to work as a basis; so that a generation profits by the experimental successes, and oftentimes by the failures, of its forefathers. Higher education has also enabled us in some measure to begin where our fathers left off, so that we must never be carried away with conceit at having been fortunate enough to live in the present age, and overlook the fact that the centuries before the one just completed have produced some of the highest skill the world has ever seen—in such stupendous works as Stonehenge, the Pyramids, Indian temples, the great wall of China, the Grecian temples, and Roman works of engineering in all countries; all of which were carried out ages ago, and without the assistance of the mechanical appliances and highly finished tools we are accustomed to in the present day. These reflections teach us to moderate our pride, and feel that previous generations have given us ideas which we, with better appliances and a greater knowledge of the earth's resources, are able to develope and improve upon.

A few words here as to the rise and progress of our Society may not be uninteresting. Founded in 1854, we had for the first five or six years a membership of about 100, which steadily rose until in 1869 we had 436 members. The following year showed a decrease to somewhat below 400. This number remained fairly stationary until 1888, when it again reached 400, advancing steadily every year until 1893, when we numbered 522, dropping, however, in the succeeding year to 502, and in the following year to below 500. The year 1897 saw our membership reduced to 468, from which figure we gradually rose to 500 in 1900.

I am pleased to be able to state that the financial position of the Society continues to be most satisfactory. As you will shortly have the statement of accounts and balance sheet for 1900 in your hands, I need only observe that they show that the utmost economy has been exercised in regard to the working expenses, and that notwithstanding the increased cost of the last published volume of our Transactions—owing to its greatly increased bulk—there is a substantial excess of income over expenditure, whilst we also have an extremely satisfactory accumulated fund.

Death has, I regret to say, deprived us of three of our Honorary Members in the persons of M. Samson Jordan, the Right Hon. Lord Armstrong, and Dr. William Pole. M. Jordan, who was elected in 1874, was the distinguished French engineer and metallurgist. He was born in 1831, in Geneva, and was educated in the technical schools. He constructed, amongst other works, large blast furnaces near Marseilles, which were the first in France built for the purpose of smelting the pure rich iron ores from Elba, Spain, and Algeria, with coke as a fuel; he was also the manufacturer of a special quality of cast iron. In 1865 he was appointed a professor of metallurgy in Paris, which appointment he held at the time of his death. M. Jordan was a Past President of the Société des Ingénieurs Civils de France and a member of the Iron and Steel Institute of Great Britain.

Lord Armstrong was born in the north of England in 1810, and early showed his mechanical tastes, and his many inventions gave him a world-wide reputation. In spite of his mechanical proclivities he commenced life as a lawyer, and was actually in practice as a solicitor at the time of his first invention—a hydro-electric machine—large numbers of which were constructed for the London Polytechnic and scientific institutions on the Continent and in America. Then followed an adaptation for working cranes, one being erected on the quay at Newcastle-on-Tyne from which similar cranes have sprung and which have been introduced into all parts of the world. This invention earned for him the Society of Arts Albert Gold Medal and his election, although a lawyer, as a member of the Institution of Civil Engineers. He founded the well-known Elswick works in 1847 for the manufacture of hydraulic machines, giving his whole time and attention thereto. The outbreak of the Crimean war led his thoughts to the question of armaments, and resulted in his numerous inventions and improvements in the manufacture of breach-loading guns and heavy ordnance which are now so well known. Lord Armstrong was elected an Honorary Member of the Society of Engineers in 1889. He was a Past President of the Institution of Civil Engineers, and three times President of the Institution of Mechanical Engineers.

Dr. William Pole, F.R.S., was born in Birmingham in 1814, and was brought up to the engineering profession, which he followed in the Midlands until 1844, when he was appointed Professor of Civil Engineering in the Elphinstone College, Bombay. At the end of three years he returned to England and commenced practice as a consulting engineer. In 1859 he was appointed Professor of Civil Engineering at University College, London. He was also lecturer to the Royal Engineer Establishment at Chatham. He was a member of several Royal Commissions, namely, those on iron armour in 1861, on railways in 1865, on water supply in 1867, and on the Thames pollution in 1882. Dr. Pole was for many years the Hon. Secretary of the Institution of Civil Engineers, of which he was a member for more than sixty years. He was elected an Honorary Member of our Society in 1867.

One of the vacancies thus created has been filled by the present President of the Institution of Civil Engineers, Mr. James Mansergh, who, having consented to be nominated, was duly elected as an Honorary Member by the Council.

The eight papers read at our ordinary meetings during the past year have been of great interest and were well up to the standard of those read in previous years. Commencing with February, our late President, Mr. Henry O'Connor, as a gas engineer, gave us in his inaugural address a very interesting *résumé* of the manufacture of coal gas and the plant and apparatus connected therewith. We had at our March meeting a paper by Mr. Richard F. Grantham, entitled 'The Closing of Breaches in Sea and River Embankments,' special reference being made by the author to the serious damage done by the high tide of November 29, 1897, to the banks of the tidal rivers in Kent and Essex. Various methods of closing breaches generally in embankments and walls were described. Mr. Grantham, who has previously favoured the Society with a paper, was awarded the Bessemer Premium for this paper.

'The Disinfection of the Maidstone Water Service Mains,' by Dr. G. Sims Woodhead and Mr. W. J. Ware, was the subject of the paper at the April meeting; the method of applying the disinfectant to the mains was described, and also the method of cleaning mains and reservoirs. Owing to the then recent epidemic in Maidstone this paper was received with great interest by a large audience.

At the meeting in May, Mr. Brierley D. Healey read a paper on 'The Economical Disposal of Towns' Refuse,' reference being made to methods of refuse disposal hitherto adopted, with cost and details of working expenses; a description of various modern furnaces for destructors was given, and tables of the results of various types of destructors.

Mr. Algernon H. Binyon's paper, entitled 'Notes on Electric Traction,' at the June meeting, commenced by making comparisons between the street traffic of London and that of other cities, and gave a description of the overhead trolley system, making special reference to a combination of electric lighting and traction plant.

The first paper after the summer vacation was read at the October meeting by Mr. Robert Henderson, entitled 'Paper-making Machinery'; the paper was an exhaustive one and described the various stages of paper-making, the construction of paper-making machinery and fittings, in a very clear manner; this paper was awarded a Society's premium.

Mr. C. Rous-Martin's paper at the November meeting—'Notes on English and French Compound Locomotives'—also received a Society's premium; the introduction of the compound system on the London and North Western and the Great Eastern Companies' systems was referred to, with an account of the advantages and drawbacks of the respective methods. The adoption of the de Glehn system on French railways, with its merits and results, was fully gone into.

The last paper of the session, at the December meeting, was by Mr. Henry C. H. Shenton on 'Recent Practice in Sewage Disposal,' and described generally the present systems of disposal with special reference to the septic tank and bacteria beds. The paper dealt very fully with the subject, evoked a good discussion and was awarded the President's gold medal.

During the past year the following visits were made, namely, on June 20th to the Thames Ironworks, Blackwall, where an opportunity was afforded of inspecting, while in course of construction, two first class armoured battle ships, *Duncan* and *Cornwallis*; the visit was very well attended, and after inspecting the method of construction, and hydraulic machinery and tools employed therein, a very interesting tour of the firm's engineering shops was made. The Thames Ironworks Company have, on several previous occasions, allowed the Members of the Society and their friends to view these very interesting works.

On July 18th a visit was paid to the School of Gunnery at Shoeburyness, by the kind permission of the Secretary of State for War. Colonel J. F. Bally, R.A., the commandant, very kindly arranged a special programme of experimental practice, which was highly appreciated by all present.

The third visit, on September 26th, was to the Beckton Works of the Gas Light and Coke Company, when the whole of these well-known and important works were inspected. This visit was a very instructive and enjoyable one.

The Society being established "for the advancement of the science and practice of engineering," naturally embraces every branch of the profession. This renders it, in my opinion, an excellent institution for those engaged in the work of a municipal engineer, as the holder of such an appointment is expected to have a knowledge of the engineering details of the thousand and one subjects that are discussed by the committees, from whom he takes his instructions, and for which this Society eminently prepares him. The greater part of my life having been spent as a municipal engineer, I purpose drawing your attention to one or two matters relating thereto, which are well worthy of attention, and in which, although great improvements have been made, much remains yet to be done. I refer especially to work in connection with the health and comfort of those dwelling and working in our towns and areas of dense population, and my remarks must be construed as referring to the older towns rather than to those manufacturing districts in which new centres of population have sprung up and developed in accordance with modern ideas.

No business man or large manufacturer would ever dream of working with a machine requiring repairs without attending to them, neither would he allow a machine of fifty years ago to be used if he knew a modern one would do his work better and more quickly. The same principle should apply to our public works, and in stating this I especially refer to underground works of sewerage: "what the eye ne'er sees the heart ne'er grieves for," is an adage well applicable to this work, and obsolete, defective sewers are often allowed to exist because their condition is not seen and because their reconstruction would mean another fraction of a penny in the pound on the rates, whereas enormous sums are spent in what are often doubtful improvements. Far be it from me to deprecate any public improvements, but I do say that the cleansing, repair and reconstruction, if necessary, of all old sewers should be looked upon as being quite as important for the public health as the removal of infectious patients from our midst. If the surfaces of some of our streets could be made transparent and the condition of many of the sewers observed, a state of affairs would often be revealed that would meet with universal reprobation.

Before the introduction of stoneware pipes it was the general custom to construct all sewers of brick, the sewers being made sufficiently large to admit of the passage of men for the purpose of cleansing, flushing and examining the connections of the numerous house and other drains. The average size of sewers was about 5 feet by 2 feet 6 inches, formed with a semicircular arch, vertical sides and slightly curved or flat invert. In the invert catch-pits about two feet deep were constructed for retaining sediment for periodical cleaning. Ventilation, if provided for at all, was effected by means of vertical shafts opening on to the roadway. These shafts, however, were generally quickly covered up as an easy means of satisfying complaints arising from the sewer gas emanating from them.

Instead of these sewers being self-cleansing they formed, as may well be imagined, a series of elongated cesspools, giving off foul emanations to the detriment of the health of the surrounding occupiers and the public using the streets. These old sewers were mostly cleansed by contract, and for years were seldom visited by any but the contractor's men, if even by them.

Until a comparatively recent period the foregoing description applied to most of the sewers in the centre of London, and there still exist many that should be condemned forthwith. Our local authorities, however, have recently dealt with many of these old sewers in a satisfactory manner. One case has come under my own supervision, viz. that of the sewers in the streets to the south of the Strand forming the Adelphi. Five years ago the local vestry instructed me to advise them as to the best scheme for remedying the defective condition of the house drains in that neighbourhood. I reported that no system would be satisfactory unless the vestry put its own house in order by remodelling the sewers, which were as much at fault as the house drains themselves. My report was accepted, and new pipe sewers have been constructed in the several streets with adequate ventilation and proper inspection chambers and flushing arrangements.

The scheme involved the construction of a new deep sewer in the West Strand at a greater depth than the old one, so as to allow for a better fall for the drains from private property to the sewers. This reminds me of a defect in our local administration which I trust the working of the new Borough Councils will remedy. I refer to dual control, whereby the local authority only has to deal with the drainage of new or altered property, and the County Council the superstructure, the result being that new basements were often got out without any regard to the level of the sewer, and the last thought of the builder (who was legally responsible for the application, and then could not be compelled to submit plans to the local authority) was to apply to the vestry for the depth of the sewer. The consequence is that many basements are below the level of the sewer, necessitating pumping up the sewage, or allowing that part of the basement below the level of the sewer to remain undrained.

The original sewer constructors had a good idea, for which all credit is due to them, and that was in making large sewers so that access could be had thereby to the private drain outlets without breaking up the streets, thus in a way leading to the introduction of subways. And this leads me to this most important matter in connection with town administration. I have always been an advocate for subway construction (having a few years ago given the Society a paper on the subject), and I had intended making the subject of street subways the leading feature of this address, but I have been forestalled in that the president of the Society of Architects, in his inaugural address last month, made it his chief theme. I should, therefore, to a great extent, be repeating what has already been so ably and exhaustively said in this respect were I to do so. I venture to think, however, that it is more the province of an engineer than an architect to carry out the construction of subways; at the same time, it is satisfactory to know that other bodies recognise the importance of the matter.

It is difficult to understand why more headway has not been made with reference to the general adoption of a scheme of subways throughout London. The idea is of course beset with difficulties, but as there should be no such word as "cannot" in an engineer's dictionary, so there should be no insuperable obstacle to an extension of the subway system throughout London. The late Metropolitan Board of Works, and subsequently the London County Council have constructed subways in most of their new thoroughfares, but in my opinion they are too small for general adoption, and were only carried out in a half-hearted manner, as no statutory power has been obtained to compel the companies who have mains in the streets to use the subways.

The City subway in Queen Victoria Street is already overcrowded with pipes, and the County Council's subways will suffer in a similar manner before long. The whole of the street (unless it be of an exceptional width) should be undermined, utilising the central portion for the subway, and the side-portions as cellars, in connection with the several frontages, let off to give a return for the outlay. The sewer should be beneath the floor of the subway, and also the "through" gas and water mains if necessary. The recent excavations made in the neighbourhood of St. Paul's and the Mansion House are instances of an enormous outlay in laying the conduits and a great inconvenience to the public, besides being a very poor forecast of any improvement in this direction for some time to come. By the subway system we could guarantee the subsoil of our streets free from deleterious matter such as leakages from drains and gas pipes, which now exist from difficulties in locating them. If placed in a subway any defect could be discovered immediately it occurred.

The cost of construction is naturally the chief obstacle, but I claim that even an estimate of from 50,000*l.* to 80,000*l.* per mile would yield a return, and a good one too, if the total amount of all the money now spent on excavations and making good were to be devoted to payment of interest on the capital.

My remarks as to keeping machines up to the highest state of efficiency apply equally to the construction of our street pavements; but I will not weary you by any lengthened statement under this head further than to mention the fact that it is the worst of all economy to try and save money in road repairs. The surfaces of all roadways should be regularly watched and any repair effected directly it is needed, and the "life" of a pavement should not be continued after it has done its work, i.e. served its allotted time. The London County Council in their scheme for advancing loans for street works give a very fair time for repayment, which time is their opinion—and a good one—of the life of the class of pavement for which such loan is granted, and the local authority should be well satisfied if the pavement lasts for that time in a fair condition. Instead of this the engineer's advice is often ignored, and pavements have to do duty for several years after they have become worn past repair. The result is endless abuse of the poor official responsible for its maintenance, by reason of inefficient scavenging which is impossible with any but a good pavement. If we had subways, I am strongly of opinion that all street pavements would last many years longer than they do now, for it is through being repeatedly broken up for laying pipes and conduits that repairs are so frequently needed.

Included in a municipal engineer's duties, are works of sewage disposal, scavenging and other matters that have been dealt with recently in papers read at meetings of this and kindred Societies. I feel, however, that I must refer to one other matter in which the municipal engineer will be called upon to extend the scope of his work in the new century—I mean cremation. I have always advocated this method of disposing of the dead, and, to those, like myself, who have had the gruesome task of witnessing a wholesale removal of the contents of a churchyard by reason of street improvement works, little inducement is needed to favour some method whereby we, and those belonging to us, may be saved from ever reaching such a condition as that revealed by the work of disinterment just referred to. The Corporation of Hull have recently opened a public crematorium which has been erected on a site adjoining one of the town cemeteries, consisting of a hall or chapel, and an incinerating chamber. The cremating apparatus is a furnace of the regenerating type in which the degree of heat can be regulated very exactly, there is no smoke and very little flame before the body is introduced, the process occupying about an hour. There is an opening through which the ashes, composed of the inorganic bases of the bones, are swept for depositing in a suitable receptacle. A charge of one guinea is made for cremating residents within the city and three guineas for strangers. It is to be hoped that these charges, small as they are, will be reduced so as to allow the poorer classes to adopt the method if they wish.

I venture to predict that before the middle of the present century we shall see a crematorium forming part of the accessories of every large town and borough in this country.

Having for some time past been principally occupied with the science of heating and ventilation, I think a few remarks as to its progress and development may not be out of place, and especially with reference to domestic work. With regard to domestic heating the word "progress" is more expressive than applicable, for when we look back to the time preceding the last forty or fifty years, or even later, we find practically no progress whatever was made. The open fire, still so much in vogue, prevailed from the time when the custom of log fires in the centre of the room or hut was given up. But the central fire, although perhaps not so cleanly, was a better means of diffusing warm air equally over the apartment than by an open fire on one side of the room. It is surprising to what a small extent what are now well known and efficient systems of heating have been adopted for domestic warming.

Prejudice in favour of an open fire is naturally very strong, for an Englishman's idea of " home " instinctively reminds him of the "hearth" around which his family assembles, although they may be scorched by the fire on one side and chilled by draughts and want of diffused heat on the other. Old associations and cheap fuel no doubt tend to cause the open fire to be retained, and there should be no wish to abolish our family instincts, but I do urge that an open fire should be supplemented by some system of warming whereby an equable temperature in all parts of the room can be assured without preventing the admission of fresh air which is equally essential for our comfort and health. The system of warming by means of circulating pipes and radiating surfaces, properly arranged with due regard to producing a uniform temperature, can readily be applied to any building. Our American cousins have set us an example in this respect by adopting some improved system in most of their public and private buildings. We are now beginning to follow in their steps, and it is becoming very general to make some system of heating an essential in all modern buildings, either alone or in conjunction with an open fire.

Steam, water, and air are the three media for circulating warmth now in general use; steam and hot-water being attended with better results than hot air. In both steam and hot-water systems the circulation takes place through iron pipes and radiators as heating surfaces, various kinds of boilers being used for generating heat. In designing an efficient system care must be taken to have a boiler of greater capacity than is actually required, and to so arrange the heating surfaces in each apartment that an uniform temperature is ensured without any draughts from air inlets, doors, and windows. It is essential for success to have the radiating surfaces well distributed; the drawbacks of an open fire are repeated if a few heating surfaces be provided at a high temperature instead of a greater area of surface at a lower temperature; if the heat be too great the air is liable to be rendered less pure.

The relative advantages and disadvantages of steam and hot-water heating have been very much debated, the advocates of each system holding strong opinions respecting their own special claims. It is impossible to draw a hard and fast line, and there is much to be said in favour of both systems. In some cases steam is more suitable; on the other hand many installations give better results if a hot-water system be adopted.

America may be said to have been the pioneer in the matter of heating, and their engineers in the past were almost unanimously in favour of steam as a heating medium, although now they are changing their opinions very largely in favour of hot water. The adoption of steam in the United States can readily be understood, as steam pipes are more quickly heated and the radiating surfaces can be made to vary more readily with the changes of temperature, which are much greater than in this country, often fluctuating as much as from 20° to 40° in a few hours. A higher temperature can also be obtained by means of steam. We have perhaps been too ready to follow their example by adopting steam as a heating medium in our installations in this country, because this climate is not subject to the rapid and extreme changes of temperature experienced in America.

It is now found that there are many drawbacks to a steam heating apparatus, and hot water, which was a few years ago out of favour, is now looked upon as preferable in many instances, especially for domestic work. Steam heating may be divided into high pressure and low pressure, and is well suited for heating large buildings and institutions composed of detached blocks of buildings, as it can be conducted to a considerable distance. Moreover, in large institutions, an engineer-in-charge is generally at hand to supervise the apparatus, steam being required for motive power, part of which can well be applied for heating purposes. Steam is not adapted for private houses, churches, or institutions where skilled labour is not permanently employed. In such buildings hot water forms a far better system as being more easily managed and not requiring such constant attention. One of the reasons for adopting steam, viz. that a greater heat can be obtained, has proved to be one of its chief drawbacks, as the temperature cannot be controlled to such a nicety as to prevent the warmed air from becoming overheated and unhealthy. Consequently, for a steam installation, either the low-pressure system or atmospheric steam heating is now generally adopted as giving results similar to hot water.

Although great strides have been made in advancing our knowledge of heating, much still remains to be done, and the want of reliable statistics, results of tests and formulæ for future guidance is much felt. Owing, however, to the fact of both steam and air being invisible it is extremely difficult to ascertain the precise action of either in a circulating system, whereas movements in a water apparatus can easily be noted by using glass tubes for experimental purposes. It is impossible to exclude air, water itself containing from five to ten per cent. of air which finds its way into the pipes with the steam, and if the condensed water be used over again the presence of air is still in the system. As far as can be ascertained the air, in addition to accumulating at the highest parts of the circuits, will adhere to the sides of the pipes and inner surfaces of the radiating plant. It has been found exceedingly difficult to remove all this air, which seriously militates against success, especially in the low-pressure system. Air produces what is technically known as "hammering," which is practically a series of shocks, the pipes being subjected thereby to violent concussions detrimental to the whole installation, and causing want of faith in the apparatus on the part of the uninitiated.

Water of condensation is another cause of trouble in a steam system, a steam pipe containing both water and air being subject to oscillations and displacements which are not thoroughly understood, although it is pretty well accepted that when a pipe contains air alone the shock due to its presence is less than with water. Air being more elastic than water, forms a cushion which acts like a spring to the hammer blow ; whereas should water come into sudden contact with the steam in the closed end of a pipe, sudden condensation takes place, destroying the cushion, and causing a violent shock.

Many attempts have been made from time to time to overcome the difficulties caused by the presence of air and water, the provision of air taps and steam traps at such places where either air or water could accumulate being the generally adopted method. An American system has, however, recently been brought out, and is now being extensively introduced into this and other countries, by means of which air is removed from the whole of the pipes and radiators before steam is admitted, by creating a partial vacuum throughout the whole system, a direct vacuum pump being employed to extract the air, together with the condense water. Branch return pipes are connected to the bottom of each radiator at the opposite side to that at which steam enters, and a specially constructed thermostatic valve is placed between the branch pipe and the radiator.

In circulating steam at or below atmospheric pressure the creation of a partial vacuum in the entire system, before the admission of steam, is essential, and to ensure perfect freedom from air this vacuum should be maintained so as to come into operation every time the system is heated up. Moreover, if the system be entirely freed from air and water, much better results are obtained by reason of the inner surfaces being perfectly free for close contact of steam.

Steam at atmospheric pressure naturally gives about 212° F., and with a pressure of from two to four pounds from 220° to 227°. Low-pressure hot water circulates at any temperature less than boiling point (212°), the temperature being generally about 170°–180° for the water in the apparatus. Thus a temperature of about 160° to 170° is obtained on the surfaces, and the fact that you cannot get a higher temperature in a low-pressure apparatus if you wish, makes this system far preferable to steam for domestic purposes.

The high-pressure system of hot water, like steam, requires skilled supervision, hence it is not well adapted for domestic work, and the failings of a steam apparatus are exaggerated in the case of high-pressure hot water, added to which, fire insurance companies require a higher premium where this system is used.

Warming by low-pressure hot water is by far the best for small installations, and those institutions where there is not a thoroughly competent engineer in charge, as it is capable of being controlled by an ordinary caretaker or domestic servant without any fear of accident. The temperature of the radiating surfaces being lower than in steam installations naturally necessitates a slightly larger radiating surface.

There are numerous kinds of boilers in the market for heating water. Some form of independent boiler is most suitable for moderate sized installations, whilst for larger ones a saddle or Cornish boiler may be used. In all boilers the grate surface should be slightly above the lowest part of the waterway, so as to allow for drawing off any sediment. It is not wise to combine the heating for domestic supply, such as baths and lavatories, with that for a warming apparatus, as discoloration of the water ensues, additional sediment is formed in the pipes, and if large quantities of water be drawn off for baths, &c., the heating system will be cooled down. A separate boiler should therefore be provided for the heating apparatus, and in determining the size of the boiler consideration must be paid to the following important matters, viz. amount of radiating surface, heating surface in boiler, grate surface, and also fuel consumption.

The amount of radiating surface can be computed when the conditions of the room are known. A good rule is to allow about 12 feet of surface to every 1000 cubic feet of air to be heated, in order to get a temperature of about 60° in the room to be warmed; but much depends upon such conditions as the area of window surface, number of outside walls, situation of building (whether exposed or not), average range of outside temperature, and so forth, that it is impossible to make a fixed scale for all cases.

The heating surface in the boiler should equal about 1 foot of direct surface to 25 feet of radiation, the grate surface being about 1 foot of grate to every 20 feet of direct boiler surface. In these particulars again we have not arrived at any fixed standard or rule as to the proportion of grate surface to heating surface, and these are approximate figures, much depending upon the style of boiler and quality of fuel. When a fire is required to last for a long period, the proportion of grate surface to heating surface must be larger than with a continuous quick fire.

The boiler should be fixed so as to give plenty of rise or lead for the flow, and all pipes should be made of a diameter sufficiently large, both as regards the mains and branches, to ensure an easy flow throughout. Special care must be taken that all bends and branch pieces should be made as easy as possible so as to afford a minimum of friction in the pipes. Failure in an installation is generally attributable to want of attention to these details, or by reason of air pockets and short circuits being formed through the scheme not having been planned by an expert, and it is the careful consideration of all these unconsidered trifles as some would call them that leads to a successful issue.

The circulation of hot water, although apparently simple, is very easily adversely affected, and it is only by great and close attention to detail that success in a scheme can be guaranteed. Every effort should be made to produce rapid circulation, and an apparatus should be designed so as to give equal resistance to the flow of water at all points to ensure as nearly as possible equal temperature throughout.

Radiators for hot water can be the same in construction as for steam, and when designed with loops and castings with embossed decorations tastily painted, they can be made to have a pleasing and ornamental appearance. Many people still hold the idea that a hot-water installation must have coils of large pipes and large flow and return pipes, all of which are very unsightly. The system of radiators and small supply pipes (but not too small for efficient working), however, is just as applicable for hot water as for steam.

The construction of the piping and connections and care in fixing affect the circulation of hot water far more than steam, and in this respect we are not so anxious to improve as our American neighbours. For instance, an engineer recently wanted some Y pieces or easy Ts as they are sometimes called, for wrought piping, and after trying all the well-known British manufacturers he was obliged to get them from America. There is a big demand for such connections at the present time, and yet no one in this country thinks it worth while to manufacture them, the reply being that a square T is quite as good. A man does not get what he wants but what the person he purchases from thinks he ought to have. Comment here is needless! Every facility should be given in the connections for an easy flow of water, and it is only by specially arranged junctions that a lead can be given. The mere fact of joining up two lengths of wrought piping without filing or reaming the edges will militate against the circulation. These points are mentioned to emphasise the necessity for studying the smallest details.

Air accumulates in a hot-water system to a small extent, but can readily be got rid of by the provision of air taps or automatic air valves. To avoid any incrustation in the boiler and pipes by reason of hard water it is better to fill the system with soft water, allowing for a supply tank large enough to take an expansion equal to one gallon for every thirty-three in the system. The supply pipe should be connected to the main return near the boiler and provided with a leg or syphon to prevent circulation into the supply tank. This leg should have a plug for drawing off the water and periodically cleaning out. Thus, for a comparatively small outlay a low-pressure hot-water system can be fitted up in a house, and if skilfully designed will prove a great convenience to the occupiers, by warming the air throughout the house where fires are not regularly going. By reducing the number of fires it will economise the coal bill, and the labour of cleaning due to dust necessarily arising from open fires, and be the means of reducing domestic labour, which is now so difficult to obtain.

Want of attention and intelligent working of a system when installed are the difficulties met with by the engineer, who having designed a satisfactory heating system, has his scheme condemned, because it does not receive ordinary attention in management. Take a church or chapel as an instance—a thoroughly efficient installation is put in sufficient to heat the building on the coldest day in winter to an uniform temperature of say 60°. The apparatus is handed over to the verger, whose only study is to make his working hours as short as possible, and so long as he can get a good fire in the boiler he thinks his part of the work is done, although he has definite instructions how to act on other than the coldest days. The consequence is that on a mild spring morning everything is done as though it were the depth of winter; valves are left open and a huge fire is built. The congregation arrive and suffer from over-heating, they then condemn the apparatus, intimate that the engineer does not know his business, and find fault with every one and everything but the man who, by want of attention to his duties, has earned their condemnation.

The question is often asked, "To what distance can you guarantee to circulate hot water from the boiler?" The reply is that much depends upon the power of the boiler and protection of the pipes. A company exists in Toledo, a town in Ohio, formed with the object of supplying hot water for heating purposes to premises within a certain district, and I am informed that hot water has been conveyed to places $\frac{3}{4}$ of a mile distant from the boiler station. The water was, however, super-heated by exhaust steam, and at a point $\frac{3}{4}$ of a mile from the station lost 12° F. We are now accustomed to hydraulic power being supplied similarly to gas and water supplies; why should we not have hot water for heating supplied in a similar manner? More generating stations would of course be required owing to the limited distance to which hot water can be taken.

Heating by means of hot-air stoves is the least desirable of all systems of warming, as the air in being warmed impinges on highly heated surfaces, thus rendering it to a great extent burnt and far from healthy when delivered into the several rooms to be warmed. The numerous air ducts and flues necessary for conveying the heated air are also liable to become foul and full of dust and substances deleterious to health. An instance recently came under my notice in the case of a person who erected a large house in the suburbs of a provincial town. He was expatiating to me on the "up-to-date" house he was building with special reference to the system of warming and ventilation on the hot-air principle. Meeting him shortly after he had occupied the house he complained that the hot air was too much for him, and he felt sure particles of dust found their way through the ducts into the rooms, and informed me he was having the hot-air stove taken out, and the chamber it occupied filled with coils for hot water. He is now perfectly satisfied, having fixed a small boiler in the basement for heating the water in these coils around which warm air circulates before being delivered into the house. This is an instance—and many more could be cited—where serious objection has been taken to warming by hot-air stoves. In the system referred to the air ducts still remain; it would, however, have been better if they had been abolished and an entirely new hot-water apparatus provided on the direct system.

Ventilation and heating are so thoroughly dependent on each other that reference must briefly be made to the systems of ventilation adopted at the present time. No doubt the older members of our Society can remember the window tax. The fact of such a tax having been in existence within the past generation shows that the progress of ventilation has been equally slow with that of heating. Even the Government of that day paid so little heed to the important question of light and air as to impose a tax upon windows. One can hardly credit that such legislation could ever have existed.

Ventilation can be divided mainly into two classes, viz. natural and mechanical. The former relies upon the natural movements of air, and the latter on mechanical propulsion and exhaust. The advocates of either system are numerous and hold very strong opinions as to the advantages of each. Time will not permit me to go thoroughly into the merits and demerits of each system. Suffice it to say then that each has its advantages and disadvantages, and, like heating, it is impossible to adhere to one scheme for every class of building. What is required is to provide as much pure air as possible without causing draughts, and to extract it sufficiently frequently to provide the requirements of those occupying the apartment, whether the building be a hospital, a church, or a dwelling.

Want of attention to an apparatus after it has been installed appears to be the evil in most systems, it is impossible to have pure air introduced through foul ducts and inlets. Very few systems get properly and systematically cleaned after they are once fixed. We might safely reckon on finding foul air ducts and appliances in almost nine out of ten systems if we examined them, no matter where or what class of building they were in. And how many houses do we find that have been built with any satisfactory system of ventilation beyond ill-fitting doors and windows as air inlets and the chimney as an outlet? I commend these matters to the serious attention of engineers, as the health and comfort of the community are at stake, and the importance of the subject cannot be over-estimated.

In conclusion, I would observe that it is possible that some may not consider this address sufficiently technical, but I hold the opinion that an inaugural address should be somewhat of a topical nature, and touch on matters of general interest connected with the profession with which we are associated, so that at the commencement of a session we are reminded of points in connection with our work in which there is scope for improvement. I have endeavoured to follow this rule, and I trust we may be favoured with papers on the subjects referred to during the session, so that all may have an opportunity of discussing the matters now briefly commented upon.

March 4th, 1901.

CHARLES MASON, President, in the Chair.

NOTES ON CERTAIN DETAILS OF DRAINAGE CONSTRUCTION.

By Gerard J. G. Jensen.

In commencing to prepare a paper on the subject of drainage, to be read before the Society of Engineers, the author, it must be confessed, experienced some hesitation. The subject is not a new one, and it is indeed doubtful whether any other technical subject has been so frequently and so voluminously written about as this. Nor is the subject unfamiliar to the members of the Society, as a few years ago an excellent paper on 'The Drainage of Town Houses,' was read before them by Mr. G. M. Lawford. That paper, it is true, had especial reference to town houses, but the principles therein laid down are, for the most part, equally applicable to other buildings, if modified according to the requirements of each case.

In preparing the present paper, the author has therefore endeavoured to avoid repetition, and to confine himself to certain details of drainage construction which might serve to amplify Mr. Lawford's paper and which, at the same time, might give rise to a profitable discussion upon points which are frequently misunderstood or which have not received the attention that they undoubtedly deserve. Perfect details make a perfect whole, and nowhere is that perfect whole more desirable or more essential than in the sanitary arrangements of a dwelling.

Chief amongst the details of construction which may be brought under notice, are a number of those pertaining to ventilation pipes. As with soil pipes, so also with ventilation pipes, the materials made use of in their construction are, it may be said, confined to lead and iron. In the southern counties lead is perhaps the material mostly used, but in the north,—from Lancashire upwards,—iron soil pipes and ventilation pipes are—in the author's experience at any rate—in preponderance. While the suitability and efficiency of iron for soil pipes cannot be denied, the use of iron for ventilation pipes is, the author submits, most inadvisable.

The interiors of soil pipes through which there is a flow of sewage are, almost from the commencement of their life, coated with a greasy film of a slime-like nature. This film, so long as it remains moist—as it invariably does when the soil pipes, or even only the drains, are in use—effectually protects the interior surfaces of iron soil pipes against corrosion. Should it fail and corrosion actually take place, the scales of rust falling into the pipe will be cleared away by the next flush of the closet. At the worst, should the rust accumulate sufficiently to cause a stoppage, the fact will soon be indicated by an overflow of sewage from the closet basin; when, doubtless, even the most indifferent householder would cause something to be done.

None of these considerations are applicable to ventilation pipes. There being no flow of sewage through them, no protective film will be formed. If of iron, even though the pipes be treated by one or other of the processes designed to protect them against corrosion, ventilation pipes will soon begin to rust in the interior and the scales of rust falling into the pipes to the next bend or offset will accumulate and cause a stoppage at that point; there being no flush to remove the scales. Once blocked, the ventilation of the drainage system will be partially or totally, and possibly permanently, interfered with, for the number of householders who cause their drains to be examined periodically is still, unfortunately, small.

To obviate stoppages by rust, rust-chambers or pockets (Figs. 1 and 2) are frequently fixed on ventilation pipes at the points where the blockages would be most liable to occur. This course is certainly advisable, and should invariably be adopted when the pipes are of iron. In the author's opinion, however, the proper cure for the evil lies in the avoidance of iron piping, for apart from the fact that prevention is better than cure, the continuous corrosion which takes place in iron ventilation pipes, seriously weakens their strength and sooner or later necessitates their replacement. The employment of lead and lead only for ventilation pipes may, he thinks, be advantageously carried so far even as to include those portions of soil pipes which act purely as ventilation pipes, when, owing to cost, strength or other considerations, the soil pipes proper must be constructed of iron; unless indeed lead-lined iron pipes are made use of for the whole stack.

It is a generally accepted rule amongst sanitary engineers, that ventilation pipes should be fixed, as far as possible, in straight lines and with as few and as easy bends as possible.

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The reason for this is obvious; since bends, by increasing friction, seriously diminish the ventilating action of the pipes, and this to such an extent that it is estimated that a single sharp bend or angle may reduce the air-current by about one-half. Bends in some shape or other cannot, however, always be avoided, and it would, therefore, be well to consider means by which their evil tendencies could be minimised or neutralised. This, the author thinks, could be arrived at by suitably increasing the diameter of the pipes at the points at which bends occur. The idea has only recently occurred to him, and not yet having had an opportunity of carrying out experiments thereon, he is unable to give any definite views on the subject. It is not improbable, however, that some of those present may have had similar ideas and that of these, some, at least, may have been tested in practice. If such be the case, it is hoped that those present who have made any such tests will give the results of their experience in discussing the present paper, or that, in the opposite case, they will give their views upon the author's suggestion.

Although much has already been written and said as regards the desirability of providing outlet ventilation pipes with cowls, the subject still remains debated. The deleterious effects of cowls which provide shelter for bird nests, which in time refuse to respond to the winds or which prove a fruitful source of annoyance by their noise, are so well known as not to require recapitulation. All these evils, some maintain, may be readily avoided by making use of a cowl which is not liable to them, and which is reliable under all conditions. Whether such a cowl actually exists outside the minds of patentees is perhaps questionable, but it may prove interesting to record a case in which a cowl which, at the time, thoroughly fulfilled its duties, proved a source of danger by its very efficiency. This cowl was fixed upon the outlet of a soil pipe which received the discharge of two closets, and it so happened that whilst the cowl created an upward current in the pipe, the discharge of the lower closet tended to create an equally strong downward current, with the almost invariable result that the water contained by the trap of the upper closet was sufficiently syphoned out to destroy the seal of the trap. This experience tends to strengthen the opinion which the author has long held; that the use of cowls should be avoided, and that nothing can exceed in efficiency a copper-wire guard (Fig. 3) as a terminal for soil pipes, if not also for all other ventilation pipes. This opinion applies equally to those cowls which are designed to prevent "blow-downs," and which are advocated by many. If such a cowl is efficient, then the resistance which it offers to a downward current of air, created by the discharge of a closet, must be overcome. If it is not, the probability is that syphonage will take place. The free ingress of air to the soil pipe at the right moment is much more important than the extraction of a large quantity of air or the prevention of an occasional back-draught.

Whilst, theoretically, there should be little or nothing obnoxious or dangerous in the air discharged by the outlet ventilation shafts of skilfully-designed and efficiently-constructed drainage systems, yet it is desirable that the openings of these pipes should be placed in positions in which the liberation of foul gases would be attended by the least possible risk of danger to health. There are times, even in the most perfect system of drainage, when, owing to a temporary insufficient supply of water or from some other such cause, a certain quantity of sewage is unduly retained in the drains and there permitted to putrefy. There are also drains in which, owing to scamping on the part of the contractor, or accidental error on the part of the designer, the retention of decomposing sewage is the rule rather than the exception. In such cases, if it has been the designer's invariable rule to select, with the utmost care, the points at which outlet ventilation pipes should terminate, little harm may result. If, on the other hand, the terminals have been placed at the most convenient (as against the most suitable) points—irrespective of the positions of windows or other openings into the house or of the prevailing winds, the results may be serious.

It is unfortunate and hardly creditable that the relationship between emanations from ventilation pipes and health should hitherto have received such scant attention from engineers, medical men and others interested in sanitation as to leave the subject utterly vague. There are no facts from which to determine the smallest distance from a window at which it would be safe to liberate these emanations. There is nothing to show whether that which would be a safe distance or height in one case would be equally so in another. Nor, even, is there any positive knowledge as to the manner in which drain and sewer air is detrimental to health. The plausible suggestion that the ill-effects of drain and sewer air are due to their action in conveying specific germs of disease has been, if not disproved, at least rendered extremely doubtful by practical experiment and experience. That they owe their evil properties to their gross chemical composition or to any one or more of the gases known to be present, has, further, been disproved by Dr. Alessi's experiments. The probability now is, therefore, that the human system is affected either by the presence of some poisonous gas which has so far escaped analysis or that there is some toxic principle present which up to the present has proved itself too subtle to be detected. Whatever the cause, however, there can be little doubt as to the effect of inhaling foul gases given off by ventilation pipes. No specific disease will, perhaps, be communicated, but the constitution will be so lowered and prepared as to fall a ready prey to a number of more or less serious illnesses. This fact was strikingly brought out by the experiments of Dr. Alessi, in which he proved that guinea pigs and rats, which are naturally immune to typhoid, proved ready victims to the fever when prepared for it by exposure to emanations from a soil pipe.

Granted this elementary and unsatisfactory state of knowledge, it is at least desirable that the engineer and architect (for architects also design systems of drainage) should err, if at all, on the side of safety. That this is not always the case is, unfortunately, only a matter of too common experience. As an instance, the author may mention that he was last year called upon to inspect the drainage of a large school in which some two hundred pupils are housed, and in which epidemics of follicular tonsilitis have periodically raged. Structurally, he found the drainage perfect. Cost apparently had been (as it rightly should be) a minor consideration, for the best possible materials, and apparently the most skilful labour—even to the point of extravagance—had been employed. Although the drainage was extensive and hundreds of various fittings were fixed in the different buildings there was not so much as a slight leakage. With the design the case was altogether different. The drains were excessive in size, laid with insufficient fall, insufficiently ventilated and practically unflushed. As a consequence they were in a highly offensive condition. The gases so generated in the drains were discharged by a number of ventilation shafts which, almost without exception, terminated—and do so now—in close proximity to and on a level with windows, the majority of which are dormitory windows.

An analysis of the cases of tonsilitis which occurred at that time and during one or two outbreaks since, showed that the cases were most numerous in the dormitories most affected by the ventilation pipes; that they were smaller in number proportionately as the dormitories were less exposed, and that one dormitory which has not a ventilation shaft in the immediate vicinity of windows which might affect it, had, as far as was known, entirely escaped. Now these facts are remarkable, since the pupils drink the same water and milk, eat the same food, and mix together freely during the day. That the tonsilitis was caused by the ventilation pipes directly is, of course, hardly probable, but that they predisposed the pupils to its attacks can, in view of these facts, hardly be doubted, even though the infection may have been imported in the first instance, and subsequently communicated from one pupil to another.

As a result of his inspection and investigations, the author made certain suggestions for minimising the risks to which, in his opinion, the drainage gave rise, but, as these were not adopted, it is presumed that the school council does not share his views. That they should not have been agreed to by the designer (the architect by whom the buildings and their drainage had been designed), was perhaps only to be expected, but it is worthy of note that one of the reasons given for this want of agreement was that there exists a ventilation pipe within a short distance of the windows of the designer's house, and that neither he nor his family had experienced any ill-effects from that source. Such an excuse would, on the one hand, be impossible, or, on the other, more convincing, were generally accepted and reliable facts and investigations available which could carry weight with impartial minds. Meanwhile, the evils at the school referred to not only continue but are probably even being aggravated. A sanatorium has been built and provided with two drain-ventilation shafts which terminate in proximity to and on a level with the ventilation openings of the wards. What, if any, effect these will have on the patients remains to be seen, but the pity is that the experiments may involve human suffering, and that the subjects to be experimented upon are not guinea pigs, nor rats, but human beings.

The subject of ventilation pipes, in their relation to health then, is one demanding the most careful study and observation; more especially since it is now not unusual to ventilate sewers also in proximity to the roofs and windows of houses; either by special ventilation shafts or, as in some districts, through the house drains. Whilst experiments would perhaps be most conveniently carried out by municipal engineers and medical officers of health working together for their own authorities, or by some such representative body as the Sanitary Institute, there is no doubt that the individual efforts of engineers generally would be productive of much good and lead towards a solution of the problem. Until that is reached, it will be well to assume the worst and to endeavour to guard against it, even at the cost of appearance and convenience. Who can say but that, by giving proper attention to the terminals of ventilation pipes, it may be possible to further increase the well-being of the community and to further reduce the death rates which have been already lowered by modern sanitation?

Coming now to anti-syphonage pipes, the author desires to draw attention to its two extremities. In the first place, it would appear that but scant attention is frequently bestowed upon the connection of the anti-syphonage pipe with the trap which it is to serve. More often than not it is found that the pipe has been branched in at the very spot at which it is most predisposed to blockage; that is, on the crown of the trap. By reference to Fig. 4, which shows such a connection, it will be seen that whatever passes through the trap with any degree of force is almost certain to be washed into the anti-syphonage pipe. That this actually does take place, is only too fully proved by the number of stopped-up anti-syphonage pipes daily met with. The evil can easily be avoided by fixing the pipes at a short distance from the crowns of the traps, as indicated in Fig. 5. In this connection it is satisfactory to note that the evil has been provided against in the London County Council's proposed new by-laws, in which it is required that the anti-syphonage pipe shall be connected with the outlet of the trap at a point not less than 3 inches and not more than 12 inches from the highest part of the trap. It is further required that the connection should be curved in the direction of the flow as illustrated in Fig. 5.

As regards the upper extremities of anti-syphonage pipes, the common practice is either to continue them up to the same level as the soil or waste pipes in connection with which they are fixed (see Fig. 6), or to branch them into the latter at a height of a few feet above the level of the highest fitting on the stack. This method is illustrated in Fig. 7, and the author submits that it is the one which is, by far, to be preferred. By adopting it, the intake of air for the anti-syphonage pipe is practically brought much nearer to the fittings than would otherwise be the case. The air would, for some distance, be drawn through a comparatively large pipe, resistance by friction being thereby reduced. At the same time some benefit will be derived by the inrush of air into the stack pipe which follows the discharge of a fitting. The system is also the cheaper one, owing to the piping and fixing saved.

Although progress in the science of arranging and constructing waste pipes cannot be said to have lagged behind progress in other portions of the drainage system, there is perhaps no other part of the sanitary arrangements of buildings in which so much conservatism has been shown. Certainly, no other reason than conservatism can be ascribed for the continued construction of waste pipes from the upper floors upon that ancient and reprehensible plan which provides an open hopper-head upon the main waste pipe at each point at which it is desired to branch in a waste pipe from a fitting (see Fig. 8). That the system is a fruitful source of nuisance must be evident to all who have given the subject a thought.

Two or three waste pipes of small diameter, conveying, possibly, highly offensive liquids, are arranged to discharge with the utmost possible amount of splashing into a comparatively large open hopper, whence the discharge is carried to the next hopper, through a pipe far too large for the purpose, and there again permitted to splash. This is repeated several times, according to the number of floors or fittings in the house, after which the waste water is allowed to find its way into a gulley trap, or possibly into an open, 18-inch long channel leading to a trapped gully. This splashing and the inefficient flushing to which these stack pipes are subjected soon permit the hoppers and piping to become coated with soap-suds, grease and other organic matter. The emanations from these are free to issue at each hopper-head and thence to be drawn into the house through the windows, in proximity to which the hoppers are usually fixed. Nor, indeed, is decomposition necessary to render the waste pipes offensive, since it is but necessary to discharge some cabbage water or other evil-smelling waste water into the pipe at one floor for the fact to be immediately evident on the various other floors of the building. It is perhaps under the, at present, fashionable flat-life that the full benefit of the system is experienced, and it must be a source of great satisfaction to the cooks to know exactly what the various families in the building are about to eat; in so far, at least, as it is possible to judge by the discharges of the kitchen sinks.

The prevention of the foregoing evils lies, of course, in the arranging of the waste pipes upon the more modern and more satisfactory plan under which the waste pipes are constructed in a similar manner to soil pipes (see Figs. 7 and 9), with the obvious difference in the diameters of the piping, and their mode of discharge. Main waste pipes from baths, lavatories and sinks should, and need, in no case exceed two or two and a half inches in diameter, and should, unlike soil pipes (under which term it is convenient to include the discharge pipes of urinals and slop hoppers), discharge over surface traps. Attention may, in passing, also be drawn to the fact that it is desirable to provide long waste pipes with slip joints, in order that expansion and contraction of the piping—due to the discharge of hot water—may take place without injury to the stack.

Reference has already been made to the 18 inches long channel, which it is not unusual to provide between the discharge end of a waste pipe and the gully trap, into which the waste water is eventually conveyed. This channel is recommended in the model by-laws of the Local Government Board, and certainly served a useful purpose when it was the usual custom to leave fittings within the house untrapped. It then minimised the risk of entrance into the house of any drain air which, from some cause or other, might find its way through the water seal of the gully trap. Similarly, it reduced the quantity of foul air drawn into the house from decomposing deposits in the miniature cesspool which then served the purpose of the modern syphon surface trap. At the present day the channel is, however, only, if at all, useful when waste pipes are constructed in the reprehensible manner already described, that is, when the waste pipes are provided with open hopper-heads. In that case, should foul air pass the seal of the surface trap, only a proportion thereof will be drawn up the waste pipe, and liberated through the hoppers near windows. The remainder of the air will be excluded from the pipe by being discharged into the open air near the surface trap. Whether this is really advantageous is open to serious doubt. If there be any advantage, it is a question which is preferable, the remote risk of foul air passing the surface trap, and being drawn into the improperly-constructed waste pipe, or the almost certainty of a nuisance being created by decomposing deposits on the surfaces of the channel.

It may be urged that the channel should be periodically cleaned by hand. This certainly is done by the few, but we have still to arrive at the time when the majority of householders will give even a thought to the condition of the drains, or bestow the care which the drainage system undoubtedly deserves. Happily, the channel may be safely dispensed with under the system of waste-pipe construction advocated by the author, and if the waste pipe is properly connected to the surface trap, then, not only will there be no danger from any foul air drawn into the waste pipe, but, in addition, any foul air passing through the seal of the trap will be drawn into the pipe, and by it liberated at a safe point, well away from all windows.

Whilst on the subject of waste pipes, the author desires to draw attention to a detail of construction which he has now for some years adopted in his own practice, and which, although made public elsewhere by him, does not yet seem to be generally known or adopted. Under the present practice of secondary disconnection, by which a surface trap is provided at the foot of waste pipes and rain-water pipes, it frequently occurs that a comparatively long branch drain is left unventilated ; the branch drain referred to being that connecting the surface trap with the main or other branch drain, in which there is a current of air. If of appreciable length, such an unventilated branch drain is contrary to the principles of sanitation. On the other hand, the provision of a separate ventilation pipe for each such drain would be both costly and unsightly. A solution of the problem lies in placing the surface trap in proximity to the main drain, and continuing the waste or rain-water pipe to it underground. This will also avoid a 4-inch branch drain which in the majority of cases, is insufficiently flushed by the discharges of the waste pipe which it serves. The method advocated is shown in Fig. 10, whilst Fig. 11 shows the alternative to be avoided. In continuing the waste pipe underground to the surface trap, it is, however, desirable to provide a cleansing eye (not shown in the illustration) at the change of direction in the waste pipe, in order that obstructions may be easily removed, should they occur.

This plan of regulating the positions of surface traps with a view to the more perfect ventilation of the drainage system, is equally applicable to manholes, the positions of which are not always chosen to the best advantage. Fig. 12, for example, shows the position, relative to drain inlets, which manholes frequently occupy. The arrangement the author submits could be greatly improved upon by constructing the manhole in the position shown in Fig. 13. By this means, in this instance, two unventilated and badly-flushed branch drains will be avoided. A slight saving in the quantity of drain-piping used will also ensue.

In the construction of the manholes themselves, some improvement might frequently be made. Manholes are provided to give access to the drains, yet it is not unusual to find them so constructed that, for want of room, the drains discharging into them can only be reached by lowering a man down head foremost. This is a position in which, unfortunately, most men refuse to work. Again, a shallow chamber may have been built of sufficient size, but provided with such a small cover that a man wishing to plug the drain finds that, by leaning into the chamber and balancing himself most uncomfortably on one hand, he can with the tips of the fingers of his other hand reach to just within an inch of the drain to be plugged. A third, and even more frequent mis-arrangement, is where the branch drains have been taken into the manhole near its outlet, leaving insufficient room for the insertion of drain-rods, should that be necessary; for there is a limit to the pliability of these rods.

As regards the channels of open manholes—that is, of manholes in which there are no access pipes (Fig. 14)—these are perhaps best constructed of concrete properly rendered in cement. If, in addition, the whole of the interior surfaces of the manholes are similarly rendered, there is a greater possibility of obtaining a water-tight structure than if glazed channels and bricks are used. Unfortunately, however, the proper formation of the channels appears to be an utter impossibility with a great number of bricklayers, and if only such men are available, then certainly, the best results are obtained by making use of suitably-shaped glazed channels. Attention must also be bestowed upon the channel benchings, since, if too flat, they will tend to collect deposits, whilst, if too steep, they will be difficult to stand upon.

Coming now to spigot-and-socket drain joints, it may be said that these are almost invariably made by inserting some strands of gasket into the bottom of the sockets, and filling up the latter with cement or molten lead, as the case may be. The object of the gasket is, of course, to prevent the jointing material from entering the piping. Its employment, however is, the author submits, not only unnecessary, but, what is more, most undesirable.

The gasket, being an organic substance, is found to decompose rapidly when moistened by sewage, and to sooner or later disappear altogether and leave a hollow space at each joint for the retention of sewage. This, of course, is opposed to the principles of sanitary drainage. Whilst the gasket lasts, moreover, it will also tend to harbour bacteria, which, in the case of pathogenic bacteria, is a serious matter, since the germs will multiply enormously in the meshes of the hemp. The joints may be well made without the use of gasket. In the case of cement joints, little more than care on the part of the workman is necessary to prevent an accumulation of cement in the piping, for, should it find its way into it, it can be easily removed before setting by the employment of a "badger." In the case of joints on iron piping, a few twists or ribbons of lead, or a cast lead ring, well caulked into the bottom of the socket, may be successfully substituted for the gasket.

The author lastly desires to draw attention to the overflows of the fittings of baths, lavatories and sinks, some of which overflows render insanitary the fittings which are provided with them. The author refers to the overflows formed by holes in the side of the fitting (see Fig. 15), to those in which the overflow pipe is masked by a shell or other ornamental device (see Fig. 16), and to others known as "secret" overflows and wastes, of which a type is shown in Fig. 17. These overflows, being but rarely flushed, and always inaccessible for cleansing by hand, soon become offensive, and it is to them that the mal-odours —"musty smells"—frequently experienced in bath-rooms, and similar apartments, are ascribable. Why these overflows should continue to be manufactured and used in new work is, perhaps, one of the wonders of house drainage, for their evils must be patent to all.

Better, and equally inexpensive, overflows are those in which provision is made for cleansing by the insertion of a brush, as indicated in Figs. 18 and 19, and those which consist of a short detachable pipe placed over the waste outlet (Fig. 20). The last-named, which are made in great variety of form, may be bodily removed from the basin for cleansing, and are easily replaced. The fact of their being in sight generally ensures their cleanliness. A similar overflow of recent introduction, which is illustrated in Fig. 21, is even self-cleansing, since, to empty the basin, bath or sink, it is necessary to partly push the overflow pipe into the waste, thus ensuring a flush of water both to the interior and exterior of the overflow pipe whenever the fitting is used. The author has of late frequently made use of fittings with these overflows, and has invariably found them to remain clean and efficient.

The author has now placed before the members particulars of what, in his opinion, are matters of considerable importance in the details of drainage construction, and has expressed his views thereon. He hopes his paper will lead to a profitable discussion, in which the views and experiences of others will be given on these and any details not touched upon by him. He trusts that both the paper and the discussion may prove of practical use to those who, like himself, are engaged in that branch of the profession which deals with sanitation, and which, conscientiously and intelligently followed, is no whit behind any other branch in importance as regards the convenience and well-being of communities.

DISCUSSION.

The PRESIDENT said that the author had given some very interesting details which ought to lead to a valuable discussion. There was one point which Mr. Jensen had not touched upon, namely, the question of air inlets. The author had mentioned air outlets, but no reference was made to the other point which was equally important for a free circulation of air. The author seemed to imply that engineers ought to plan drainage schemes so as to allow for the possibility of scamping, when he stated that "There are drains in which, owing to scamping on the part of the contractor, or accidental error on the part of the designer, the retention of decomposing sewage is the rule rather than the exception." He (the President) held that a system of drainage ought not to be designed with any idea whatever of scamped work being introduced. He concluded by proposing a cordial vote of thanks to Mr. Jensen for his paper.

The vote of thanks was carried with acclamation.

Mr. Scott Moncrieff said that to him there was a personal interest attaching to the paper, because Mr. Jensen was an old pupil of his. He thought that the paper would be accepted as one which did its author great credit. It was thoughtful, painstaking, and moderate. He considered that Mr. Jensen had pretty well proved his case in each of the points which he had raised. The advantages of some of the details which were set forth were obvious enough, as, for instance, the contrast between Figs. 1 and 2, Fig. 2 showing a provision for a receptacle for the rust which formed in iron ventilating pipes. The distinctions between Figs. 4 and 5 were equally obvious.

The subject of the paper had a bearing upon the interests of the community as a whole. The average layman was, of course, dependent upon the assistance afforded to him by his professional advisers in the matter of his domestic drainage service. During the last twenty-five years vast sums, amounting to many millions of money, had been spent in London alone upon domestic drainage. He thought that the experts, the engineer, the architect, and, in the majority of cases, the contractor, had a clear conscience as regarded the great bulk of the money which had been spent. No doubt in the early days money was spent badly, and certainly not as well as it ought to be spent to-day after the experience of the last twenty years. But the points raised in the paper were of interest, not only to the people who spent the money, but to the experts as well. If there were still open questions, it was of great importance that engineers and others should bestow the greatest possible care and attention upon them, and from that point of view the paper was not only interesting but also opportune.

The President had referred to the question of air-inlets which had been omitted from the paper. He hoped that that question would be dealt with in the discussion. One of the most interesting parts of the paper was that which dealt with the question of outlet ventilation. The case of the school which Mr. Jensen had referred to was certainly not creditable to the governing body responsible for the defects. It did not often happen that the professional adviser was confronted with such a *non possumus* as Mr. Jensen seemed to have met with in that instance. It was outrageous, when ventilation pipes in the immediate neighbourhood of dormitory windows had been shown to be the proximate cause of illness, that no steps should have been taken to remove the offence. He would venture to refer to the question of the ventilation of house-drains as affecting, not particular houses, but whole areas. He thought that there were many districts in London in which there was such a number of ventilating pipes terminating at or about the same level, each of them connected with more or less foul or indifferently flushed drains, that there must be on a still day a layer of contaminated atmosphere on the same plane, roughly speaking, as the upper windows of the houses. That raised an extremely difficult question, but it had always appeared to him that one of the obvious means of preventing danger from such a state of things was that the drains themselves should be constructed so that the amount of the objectionable gases should be minimised to the utmost extent, and that could only be done by having the minimum size of drain and the maximum flush of water.

He thought that it was most creditable that so much should have been done within the last twenty years to improve our domestic sanitation without any very drastic measures having been taken to enforce the adoption of the improvements. His own recollection went back to the first case of the adoption of the cardinal principle of disconnection in addition to the use of a trap, which was carried out by Dr. Ferguson, of Glasgow, about twenty-five years ago. Before the adoption of disconnection and through ventilation there existed the trap pure and simple, which was a poor safeguard at the best. It was interesting to remember that the whole work of modern domestic sanitation which had added so enormously to the health and well-being of the community had been nothing more than a development of the simple principle of trapping, supplemented by disconnection and through ventilation. The paper might be spoken of as dealing, from an expert point of view, with one or two residual difficulties. The underlying principle of disconnection and trapping were as much in evidence as ever they were, and the practice of modern domestic sanitation turned almost entirely upon their being carried out in the greatest possible perfection.

Mr. Jensen has made reference to the work of Dr. Alessi, a distinguished Italian bacteriologist. Dr. Alessi's experiments had been somewhat disparaged without any particular reason being given, and he thought it would be well, if there was any good reason for doubting their validity, that they should be repeated. They went to show the direct connection between sewer gas and disease, arguing from the effect the gases had upon the immunity of animals, and, if there was any reason to doubt the results, some competent authority should repeat the experiments, so that they might be either confirmed or confuted.

Mr. SHIRLEY MURPHY said he had listened with much pleasure to Mr. Jensen's paper. It had impressed him with the thought and knowledge which was now employed in the construction of house-drainage. He did not feel himself able to discuss all the questions which had been raised, and he would confine his remarks to one subject, the stability of underground stoneware drains. It had been within his experience that the stoneware drains of a public institution, laid with every care, had, after a number of years, ceased to be watertight, and he was desirous of knowing whether the experience of those who were constantly engaged in such work was of a similar kind ; whether, in fact, stoneware drains were to be considered as practically permanently reliable.

Mr. E. J. SILCOCK said, speaking broadly, he thought the members would all agree with the views which the author had expressed. The difficulty in all these matters was to get clients to undertake the work on the best possible lines. They hesitated on account of the cost.

As to ventilating pipes, the chief point was to keep them as large as possible. If they were constructed of lead instead of iron, a much greater cost was involved, and, personally, he would rather have a large iron pipe which was subject to risks of rusting and so forth, than a smaller lead pipe, for he was quite sure that the latter would not be so effective for promoting the ventilation of the drain. He almost invariably used iron ventilation pipes in his own practice, and he had generally adopted pipes which were enamelled on the inside. The enamel prevented rusting, and if the pipes were carefully handled he had no doubt they would last a very long time. As to the rust chambers, he thought that the form shown at Fig. 2 was much simpler and better than Fig. 1. Fig. 2 was a form which he had adopted for sewer ventilators of large size. It was very easy to make and very easy to clean.

With regard to the question of cowls, he had tried many, and he was not disposed to favour any particular one. Most of them were efficient under certain circumstances, but they were all liable to get out of order.

The author had suggested that ventilation pipes should be enlarged in sectional area at the bends. The suggestion seemed to be a very good one. It was carried out in connection with steam pipes, especially for heating purposes, and it gave very good results, but he had never adopted it with regard to ventilation pipes. He saw no reason why it should not do equally well for ventilation pipes as for steam pipes.

The subject of air inlets, to which reference had been made by the President, was a very different one, and he thought that the position of them was a matter of more difficulty than that of air outlets. The great difficulty was to prevent an air inlet from becoming an air outlet. There were such things made with mica flaps, and so forth, which were said to prevent the possibility of down-draught; but his experience of mica flaps was that, in a very short time, the hinges became so corroded away through the action of the sewer gases that one of them broke, and the flap hung on one hinge and refused to act, and the mica flap became more or less of a failure. For that reason an air inlet should be put in such a position that, if it became an air outlet, it would do no harm.

In town houses air inlets would probably have to be put in a very small yard or back garden, and be carried by means of pipes up the face of the building. If the air inlet was carried up to the top of the house as high as the air outlet, it became theoretically equal in value with the outlet, and the air might go in at one pipe or out of the other, just as it happened to take its fancy. In addition to that, the cost would, of course, be excessive; so that system was very rarely adopted. If the pipes were made short so as to get the outlet much higher, then there was the danger of the inlet becoming an outlet in the neighbourhood of a window. The subject was one which it was extremely difficult to deal with. Personally he preferred to omit air inlets altogether, rather than to run the risks which were present in many cases. Sometimes a case was met with in which there was a long stretch of open space adjoining the house, so that it was really possible to make an inlet on the level ground in such a position that, if it became an outlet, it would not do any harm.

With reference to the question of the life of pipes, which was raised by Mr. Murphy, he thought that there must have been some special circumstances in the case he mentioned. If the pipes were leaky it seemed to him (Mr. Silcock) that there ought to be some explanation which should be pretty obvious, such as that, although the pipes were laid on concrete, they must have been laid on a yielding foundation which allowed the pipes to sink. He had never seen any signs of earthenware pipes having become broken, or showing signs of decay, unless there was some explanation such as that. His impression was that the life of earthenware pipes was perfectly satisfactory, and he did not think that anyone need fear to use them.

Mr. R. J. ANGEL said that he had been talking to Mr. Murphy about the matter of which he had just spoken, and he had gathered from him that there was some local circumstance in the case which caused the pipes to fail. It was one to which very serious attention should be given. In the case referred to the subsoil had been drained, and that had caused a local subsidence. Although the pipes were encased in concrete, the subsidence caused cracks, and it was probably the reason why they failed.

It had occurred to him, on looking at the arrangement for retaining the rust shown in Fig. 2, that the same arrangement might also retain the fæcal matter which came down. He did not suppose that rust would come down in quantities of two or three ounces or a quarter of a pound at a time. It would probably come down in slight flakes, and not more than two or three flakes at a time. Would it not stand a better chance of getting through the trap shown in Fig. 1 than it would if it was retained in Fig. 2? He thought that the arrangement in Fig. 2 would form virtually a cesspool which would probably generate bacteria and be a source of a very foul smell.

Mr. SCOTT MONCRIEFF said it was a ventilating pipe to which the author had referred.

Mr. ANGEL (continuing) said that the question had been raised about the gasket perishing in course of time, and leaving a cavity. Would not the cavity be perfectly protected if the spigot was driven right into the head of the socket? It was always an instruction that a pipe should be driven into the head of the socket, and that would materially aid in closing up any aperture which might exist. He did not think that it would be well that the gasket should be left out. Of course it might be said that the cement which exuded from the joint would be scooped away by the "badger," but would it not be possible that strings of cement would be left in the interior of the pipe? The continual pull forward of the "badger" drew the greater portion of the cement along with it, but it was likely to leave a wash behind, which would set hard and rough. That had actually happened in a sewer at Bermondsey. The pulling along of the "badger" pulled lumps of cement away, but left the interior of the pipe coated as described, and a blockage resulted. He thought that prevention was better than cure, and it would be far better to thoroughly caulk the head of the socket with the gasket. What did it matter if a small cavity did exist? His own impression was that, in sanitary matters as in others, there was here and there a little bit too much faddism. They were rather inclined to ride a horse to death by taking it too far. He thought that the cavities were really very small, and seldom occurred in practice. Of the two evils he preferred to run the risk of the gasket.

As regarded manholes, if a manhole was built of brick, set in cement, it would be absolutely watertight. He did not like a manhole rendered in cement. In some cases where a manhole was rendered with cement, the cement would crack off owing to wear and tear by workmen, and frost, and do a considerable amount of damage. If he could not get white glazed bricks, which local authorities did not always care to go to the expense of, and which private individuals were not always liberal enough to allow for, he preferred to have blue bricks in preference to cement rendering.

In the case of the fresh air inlet, a form was recommended in the Annotated Model By-laws of the Local Government Board (*vide* Diagram No. XXIX.), which had an air inlet on the level of the street. The members were doubtless all familiar with the diagram. First of all, they would recollect the upcast shaft coming from the head of the trap. Then there was a cast-iron box at the level of the footpath, with a hinged lid, half of which was perforated and half solid. The solid part covered the pipe. The fresh air was expected to pass down through the perforated part and run round the corner and down the pipe. That looked feasible enough on paper, and was all right at first, but the perforations in the lid soon became stopped up by dirt, or blocked with snow in winter. His own impression was that there should be a down-cast shaft beginning at such a height above the footway as not to be injurious to the passer by—set in a chase in the wall if needs be—and devoid of all such things as mica flaps, and with nothing but the grating and air-opening, and carried down direct to the head of the syphon.

In the north of England they very often put a trap to a kitchen sink; in London, he believed, they did without a trap, and he agreed with doing without it because, of all the apparatus in a house, the one that got stopped most frequently was that little trap in the sink. Servants were not supposed to have any technical education, and could not be expected to look after such things, therefore people must take matters as they found them. If servants would stop up the traps, then let the traps be taken away, and the waste pipe from the sink made to discharge directly over the head of a gully. In order to prevent any smell from getting up the pipe, there was usually a little copper flap fixed on the outlet of the waste pipe outside the building. That acted far better than any trap could act.

As to the lavatory basin in Fig. 21, he did not like the arrangement. In the first place, it was a very expensive one. The simpler such an apparatus was made the better. In conclusion, he must thank the author of the paper for judiciously putting his thoughts together in the form of a paper.

Mr. Clifford Smith said that the author, when dealing with lavatory wastes, had omitted to mention bath wastes. He thought that the lavatory basins were not so objectionable as the bath wastes. He referred to the type of baths with the waste-plug carried in a casting at the head of the bath, which were particularly objectionable by reason of the accumulations they permitted, and which could not be seen or easily got at. He joined issue with Mr. Angel in his statement that engineers were a little faddy in sanitary work. He thought that if engineers could make other people a little more faddy on the present question, sanitary arrangements generally would be a great deal more healthy. If there was one thing more than another that was thoroughly neglected, not only in London but also in the country, it was the question of the sanitary well-being of a house. Nobody made a study of it except those who gained their livelihood by it, and the consequence was that if anything went wrong in the house, the evil was usually put down to some wrong condition of the drains in place of wrong treatment of them.

He had been struck with the point made in the paper concerning the rust in the ventilating pipe. No one who had had to do with the ventilation of drains could have failed to have the disadvantages of rust brought to his notice, but he did not think that the suggestion of the author to use lead pipes would answer. In the institutions with which he (the speaker) was connected, and in buildings where children or careless persons were about, lead soil pipes would be likely to invite kicks, and such pipes were not worth very much if subjected to a course of kicking. He thought that it would be better to use iron pipes lined with glass enamel. They were effective, and the enamel did not come off. They offered many advantages, and could be applied to all sorts of apparatus; so that if engineers were looking for an article that would obviate rust, they would find it in glass enamelled pipes.

He thought that the idea of increasing the size of the pipes at the bend was an excellent one. It was recognised under other conditions, as with steam at high pressure, that a bend in the pipe meant a higher velocity of the steam passing it. That was possible where the pressure existed, but with the little margin in pressure that was to be had in ventilating pipes only a decrease in speed at the bends could follow, and to prevent the friction only an enlargement of the pipe where the change of direction occurred would give the desired result. But if an increased size at the bend was adopted, it should be understood that tapered connections must be used. Otherwise there would be a square projection at the joint, and an increase in the obstacles opposing the rising air would cause an interruption of the current, and upset the whole thing. With regard to the covers to the ventilating outlets, he thought that nothing was better than that known as the beehive. It seemed to have no attraction for birds, for the reason, probably, that they could not sit upon it.

He should like the author to tell them a little more about the syphon action following down-draught. It was a remarkable thing. With regard to the school of which the author spoke, he did not think that the trouble at that school was at an end. It was very likely that the author would be called in again, and he hoped that when he was called in next time his clients would pay more attention to his advice. It was very clear that there was something faulty in the design of the system. Often the distribution of ventilating pipes was altogether bad. He had in his mind an institution in one of the sections of which outbreaks of throat trouble and diarrhœa occurred from time to time, the reason for which could not be assigned, and they were the subject of much investigation. The occupants of one of the upper dormitories in that section were most affected, and the knowledge of that led to an examination of the surroundings of that particular building, and it was found that the emanations from the ventilating pipes of the drains of an adjacent block, under certain conditions of the wind, were blown into the rooms where the illness was most frequent. These ventilating pipes were consequently rearranged, and the results carefully noted. The outbreaks of illness ceased, and it is reasonable to assume that that resulted from the removal of the pipes. He thought that instance bore out what the author had referred to.

With regard to the question raised by Mr. Shirley Murphy as to the laying of drains, he had now a system in hand to rectify. In his case the drains were laid on clay soil without concrete. He found that the clay and the drains in it had all moved, with broken pipes as a consequence, and the fault was apparently due to the pipes being laid directly on the clay, which had been affected by the very dry summers. He was now laying them on concrete. He had found country-made pipes, where laid in chalk, quite soft after being sixteen years underground, but exposure to the air had a hardening effect on them.

Dr. Farrar said that he wished to ask the author's opinion particularly on one detail which had always struck him as of very great importance, although it might seem to be a slight point and was very commonly neglected. He would venture to suggest that ventilation pipes as commonly arranged were too often a mere fetish. In the first place, speaking from an experience in country districts, he thought that they were generally far too small. Perhaps a two-inch pipe was put to ventilate a four-inch soil pipe. In the second place—and that point had been touched upon—they were very often fitted with a cap instead of being covered with a wire guard. But the particular point he wished to raise was that, too often, a ventilation pipe was constructed to go round the rain-gutter or round the eaves, and had at least four right angles in it. He did not know whether there was any formula which gave the precise amount of checking by friction that the gases would undergo in passing angles; but it appeared to him that a pipe with not less than four right angles, and carried round the rain-gutter must be almost negative in its action. He ventured to suggest that it was a very important thing that, when a ventilation pipe was put up, the eaves should be cut away, if possible, to allow for the pipe to go straight up into the air. If possible the rain-gutter should be so adapted that it should go round the ventilation pipe, instead of the ventilation pipe going round the gutter. He had succeeded in persuading several patients in the country to adopt the plan of having the ventilating pipe set off from the wall by means of iron stanchions, so that it could go straight up into the air direct. That plan might possibly be open to the objection that a pipe carried in that way would be more open to injury; but he believed that it would be the best way of fixing it.

Mr. Max Clark said that the author had very properly observed that it was small details which constituted good sanitation. He would venture to make a short criticism on the paper. Figs. 1, 2 and 20 in the illustrations were copies of a circular which was sent round a little time ago by, he believed, some firm called "the 'Loco' Draining Apparatus Company"; and, if he was correct in his recollection, Figs. 1 and 2 were wholly and solely intended to be used in connection with ventilating pipes, and were not intended for soil pipes. At the same time it was very difficult to understand how the people who sent round that circular imagined No. 2 would be cleaned out at any time if the engraving represented it correctly. The rust might fall down; but it was difficult to see how it could be got out. He should like to know from Mr. Murphy whether the failure in the drainage which he mentioned was universal. No evidence had been given on that point. Nothing more was stated than that it had failed. Of course drainage might fail in one or two places, and the defects might not be universal. One or two small faults might easily be accounted for. With regard to the observations of Mr. Clifford Smith, who had relaid the drainage in concrete, it would be natural to expect that unless his concrete was strong and very deep down in the clay it would give exactly the same result as the drainage that went before. Therefore it might be worth while to examine the drains in thirty years' time.

He joined issue with the author of the paper as to lead ventilation pipes. There were many occasions in which it was necessary to use a soil pipe, and that pipe had to carry hot water. It happened occasionally in manufactories that there was also steam. Under those circumstances a lead ventilation pipe was about the worst thing that could be put up, because it buckled about in all directions under the influence of the heat and cold, and proved a great source of expense to the people who erected it. Of course most engineers knew that if they wanted a very good thing they could have a glass-lined pipe, or one treated with Dr. Angus Smith's solution, or a galvanised one. Any of these, under the circumstances he had mentioned, were much better than lead.

Ventilation taken as a whole was a very large matter. Mr. Jensen did not suggest any methods by which they could ventilate a soil pipe in the direction of the fall of the water when it left the apparatus. Of course, anyone who had thought at all about these matters, knew that that which was called a system was under certain circumstances turned inside out. The water dragged the air down the pipe and reversed the ordinary state of affairs. That being so, it was but common sense to imagine that sanitarians would in the future change their views somewhat, and particularly the local bodies who governed the matter, and would endeavour to obtain some method which would allow ventilation in the direction of the flow of the water. He had had to do with one or two systems of drainage in London, and he had pursued that system, and he did not find it much more expensive than the method which was at present advocated.

With regard to the anti-syphon pipes question which had been touched upon, he thought that the present county council by-laws were quite clear and gave precise instructions as to how they were to be fixed. He would like the author to state in his reply how he proposed in long lengths of lead pipes to make the soil pipes gas-tight and water-tight.

He had a slight criticism to make upon the drain plan. There was, of course, another thing in drainage which was almost as essential as good workmanship, and that was to keep the fittings and the apparatus at all points as few in number as possible, each apparatus which could be omitted was so much to the good. He ventured to suggest that one of the gullies in the yard was unnecessary, viz. the yard gully, which he presumed took the rain-water or surface water. The gully which was taking the sink waste might take the surface water also.

He did not quite understand Fig. 9. He did not know whether it was supposed to be what the author desired or what the author abused. He thought that it was probable that that arrangement would syphon out the bath waste most completely.

With regard to the method which some had of ventilating drains by means of a "Buchan" trap and air inlet in the curb of the pavement, he imagined that it was quite a common thing at the present time. The grating which ventilated the trap, or which was expected to be the air inlet, was situated in the front of the curb, and in many parts of the country that sort of thing was seen over and over again. He objected to it altogether, because he objected to ventilation from the front of the house at all, in opposition to the flow. As to the manhole which Mr. Angel mentioned—he found fault with it as being too flat in the floor; under many circumstances the water backed up in the manhole and left a deposit in the flat floor; the solid matter was also washed up on the floor of the manhole by the force of the flush, where it remained and produced sewer gas, which was very objectionable. All this could be obviated by making the floor more sloping. He was surprised that in connection with the question about gasket no mention was made of pipes which were "double seal," viz. with the composition joint in front (in place of the gasket) and the cement joint outside. Of course that was a cure of the whole evil of the gasket which had been mentioned, and also for the difficulty of clearing the pipes of the cement which often exuded from the joints inside the pipe. It was a well-known fact that the dragging forward of the badger did not thoroughly clear the cement out of the drain, they required to be washed out with a wet cloth after the badger, if a good job was to be made, where the joints were made with cement.

Mr. **Jensen** said that the President in his criticisms had remarked that drainage work should be so designed that it should not make any allowance for scamping. Perhaps he (Mr. Jensen) in alluding to scamping had hardly conveyed what he intended. He meant that the design should be in all cases so good that, if scamping did take place and remained undiscovered, the evil results would be minimised. It was far from him to wish to encourage scamping. As for air inlets, he had not mentioned them, as the subject had been already touched upon in a previous paper written by Mr. Lawford. The point had been fully discussed on that occasion, and, as there was nothing new to record, any allusion made to the subject would have been in the nature of repetition.

Mr. Shirley Murphy had mentioned the case of certain drains which had sunk and cracked, and some discussion had arisen upon the point. Of course the sinking of drains was not at all unusual, but it almost invariably happened through faulty materials or workmanship, or owing to natural subsidence of the soil. In some cases drains were found to go very soon after they were laid; and in others they would last for a great many years. Upon unsuitable soil the difficulty would not be overcome by laying drains on a concrete bed. He had recently had a case at Wimbledon where the drains had been laid on and surrounded by concrete, only some two or three years ago, yet the drains had cracked through the settlement of the ground. Both the concrete and the drains had given way. He thought that the remedy lay rather in the use of iron pipes of great strength, laid upon a very broad and thick bed of concrete. Other precautions might suggest themselves when the nature of the ground was known.

Mr. Silcock had recommended enamelled iron pipes in place of lead pipes for ventilation. His own experience was that the enamel was liable to crack and that the pipes rusted behind the enamel and caused it to come off. He should say that such cracking would be very liable to occur where the drains received steam or hot water as mentioned by Mr. Max Clark. In such cases they might have pieces of enamel to contend with as well as rust in ventilation pipes. Lead pipes were certainly liable to injury by kicks, etc., but they could be protected by fixing sheet-iron guards round the portions liable to be damaged.

Mr. Silcock had said that he preferred to leave drains without any air inlet at all, if he could not place the inlet in a position in which it would be absolutely safe. He presumed that he meant in cases where the drains had more than one outlet, and in which one of the outlets might occasionally act as a ventilating inlet. If there was but one outlet and no inlet, there could be no ventilation whatever, as two openings at the least were necessary for that. As to the alternative of having the air inlet at the same level as the outlet—at the top of the roof—that would in most cases result in stagnation altogether, as the heavier gases would collect at the bottom of the drain and virtually form an air trap.

Mr. Angel thought that the evil of an open space at each joint caused by the disappearance of the gasket would not be serious. He (Mr. Jensen) took a more serious view of the matter, more especially in the case of stoneware drains with their numerous joints. The gases generated would alone be a serious objection, to say the least. The edge of the spigot did not always fit closely against the bottom of the socket as had been stated by Mr. Angel. Were that the case there would be no need to use gasket or to take other precautions against the admission of cement to the drain. Very frequently the two were so rough and touched so badly that there might be an open space of a quarter of an inch or more between them. Mr. Angel, in referring to the lavatory shown in Fig. 21, thought that many people would object to it on account of its cost. As a matter of fact, that particular lavatory was as cheap as the majority on the market. It had been specially made so, he understood, in order to compete with them.

Referring to Mr. Clifford Smith's remarks, he (Mr. Jensen) admitted that he had not mentioned baths. They were, however, much the same kind of fitting as lavatories, and did not differ from them as regarded the treatment of their wastes. What applied to one applied mostly to the other. With regard to the case of syphonage mentioned by him, he thought that that could have been due to no other cause than the two currents of air which were pulling against one another in the soil pipe. That was the only explanation he could find at the time, after carrying out various experiments.

Dr. Farrar mentioned the case of a ventilation pipe with four right angles and running round the eaves. Of course that was one of the things that should be avoided. Probably the angles would reduce the force of the current to extremely small proportions, and that was one reason why he (Mr. Jensen) had advocated an increase in the sectional area of the ventilation pipe where there was an unavoidable bend. In the particular case instanced by Dr. Farrar the bend could no doubt have been avoided.

Mr. Max Clark had desired some particulars regarding slip joints. A socket was formed on the lower pipe and the lower end of the pipe immediately over it was pushed into it, and the joint between the two made by a vulcanised india-rubber ring. In that way room was given for the upper pipe to expand into the socket on the lower pipe. He did not recommend the joint for soil pipes, but only for waste pipes.

Mr. **Max Clark** said it was found that the india-rubber rings deteriorated.

Mr. **Jensen** agreed that that was the case, and that the rings required renewal occasionally.

NOTES ON CERTAIN DETAILS OF DRAINAGE CONSTRUCTION.
BY GERARD J. G. JENSEN.

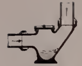


Fig. 1.

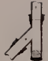


Fig. 2.

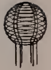
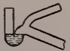


Fig. 3.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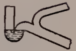
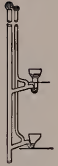


Fig. 5.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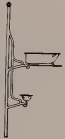
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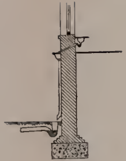
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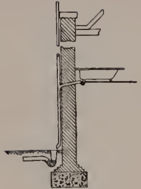
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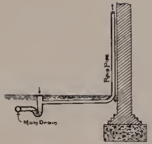
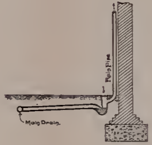


Fig. 10.



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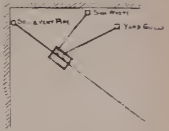

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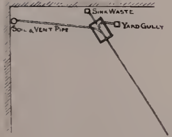


Fig. 13

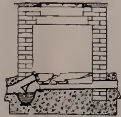
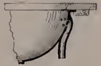


Fig. 14.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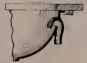
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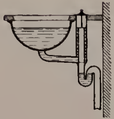
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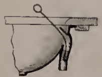
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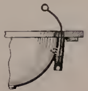
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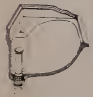


Fig. 20.

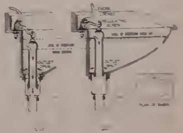


Fig. 21.

April 1*st*, 1901.

CHARLES MASON, PRESIDENT, IN THE CHAIR.

THE PRODUCTION OF METALLIC BARS AND TUBES UNDER PRESSURE.

By PERRY F. NURSEY, PAST PRESIDENT.

INTRODUCTION.

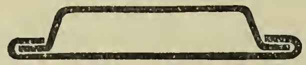
THE flow of metals, under one or other of its multifarious aspects, is a subject which has occasionally engaged the attention of both the theorist and the practical man. From either point of view, whether theoretical or practical, it forms a fascinating study, the outcome of which, under the direction of master minds, has often proved of value to the metallurgical industry. Leaving theoretical considerations to those whom they may more immediately concern, the author purposes in the present paper to confine himself to the practical side of the question. His object is to bring before the Society such adaptations of the principle of extrusion to the commercial production of rods and tubes, as have come under his notice, including one of the most interesting of its applications to metallurgical purposes he has ever had the privilege of inspecting. This is the ingenious process invented by Mr. Alexander Dick—the inventor of Delta metal—by which all kinds of metallic sections, from a simple round wire to complex designs which it is impossible to roll, and also tubes, are produced by causing metal, heated to plasticity, to flow through a die under hydraulic pressure.

The principle itself is simple enough, being nothing more than that which underlies the manufacture of bricks, drain pipes and similar articles. The practical application of that principle, however, is quite another thing, especially when it relates to the production of metallic bars and tubes of any section—bars with re-entering angles, and tubes square internally and round externally, and *vice versa*, or round inside and out with internal and external longitudinal ribs, as in the Serve tubes. The application of the principle in the branch of manufacture under consideration is not new. It has for years been applied to the production of continuous lengths of leaden wire and of leaden rod for the manufacture of projectiles for small arms, for which latter purpose the author has seen it in use at the Royal Arsenal, Woolwich. The manufacture of leaden pipes is another familiar example of its application. In these cases however lead, with its melting point of 620° F., is pressed at a comparatively low temperature and pressure, whilst in Mr. Dick's process, copper and its alloys—far less ductile metals than lead—with their melting points of about 2000° F., are operated upon at a very high temperature, namely, that of plasticity, or about 1000° F., and which temperature, moreover, varies considerably with different metals and alloys.

In dealing with the present subject, the author proposes to notice first the methods and apparatus employed in the manufacture of lead pipes for ordinary purposes, and next the adaptation of the lead pipe press to encasing telegraph cables in lead tubing, and afterwards the system and apparatus devised by Mr. Dick for the manufacture of copper bars and tubes by extrusion, by which invention he has made a very substantial advance in metallurgical practice. This sequence is appropriate both in point of time and circumstance, inasmuch as the manufacture of lead pipes under pressure claims priority.

LEAD PIPES OF THE ROMANS.

The earliest lead pipes with which the author is personally acquainted are some which were made by the Romans. He need hardly say that he was not present at their manufacture, but he inspected them some nineteen centuries later. This was at Bath in 1888, when he visited some excavations which were going on in the Roman baths there. These pipes were of a flat inverted trough-like section, as seen in the accompanying sketch.



They measured about 18 inches wide by 4 inches deep, and were made from a dished strip of lead which constituted the top member, whilst a flat strip, having its edges turned up over the edges of the upper strip, formed the lower member or base. The lead of which these pipes were made was doubtless obtained from the mines in the Mendip Hills, where lead pigs have been found bearing the stamp of the Roman Emperor Claudius, whilst others bear the stamps respectively of Vespasian and Hadrian.

Early Manufacture of Lead Pipes.

It may be of interest to note in passing that in the early days of lead pipe manufacture, before presses were introduced, the pipes were made from a short, thick, solid cylinder of lead cast with a hole through its centre of the exact diameter of the bore of the pipe. A long steel mandrel was then run through the bore and the cylinder was rolled down progressively to the required external diameter of the pipe. Another method was to draw down the lead cylinder through dies, whilst yet another was to bend sheet lead over a mandrel and solder the edges together. By none of these methods could anything but comparatively short lengths of pipe be produced, ranging from 20 to 30 feet in length.

The Lead Pipe Press.

These unsatisfactory methods of manufacture were in time greatly improved upon by the introduction of apparatus for producing lead pipes by direct pressure. The lead pipe press is arranged vertically, the hydraulic cylinder being placed beneath the floor, as in Fig. 1. The upper portion consists of a cylindrical container or reservoir R, for the fluid metal, around which is an annular furnace F, provided with a flue for carrying off the products of combustion. At the upper end of the container a steel die of the diameter required for the outside of the pipe is held in position. The die is removable so that it can be changed for any required outside diameter of pipe. Through this die a mandrel of the size required for the bore of the pipe passes upwards, the mandrel being fixed to the top of the plunger P.

In operation the container is charged with molten lead through a spout S, leading to an opening, which is closed after charging, and when the metal has reached the plastic temperature point the hydraulic press is started. The plunger attached to the head of the ram is slowly forced upwards into the container, driving the molten lead before it. The lead is thus forced through the annular space between the mandrel and the die, a perfectly finished pipe being formed, which is coiled round a drum D, as produced. After each stroke of the ram the container is charged afresh.

By courtesy of one of our members, Mr. H. F. Stanley, the author was enabled to inspect one of these presses at the

Farringdon Works, Shoe Lane, London. The container of the press is 9 inches in diameter by 23 inches deep, and holds a 4½ cwt. charge of lead. The required temperature in the container is maintained by a ring of gas jets. By changing the dies the press is capable of producing pipes from ⅜ inch to 4 inches internal diameter. The ⅜-inch pipe is produced at an hydraulic pressure of one ton per square inch, whilst the 4-inch pipe is made under a pressure of 15 cwt. per square inch. At the time of the author's visit the press was running on ½-inch water pipe, which was being made in 60 feet lengths to suit trade requirements. The charge in the container is sufficient to produce three 60-feet lengths, or one length of 180 feet. The 4-inch diameter pipes are produced in straight lengths of from 10 to 12 feet, there being an overhead arrangement for maintaining the pipe in a vertical position during extrusion. Although this press, which is on the lines of that shown in Fig. 1, has been at work a number of years, it is still giving a satisfactory account of itself.

Wylie's Improved Pipe Press.

Such then is the ordinary press employed in the manufacture of lead pipes, but which has been greatly improved upon of late years. Among others who have devoted considerable time and attention to the improvement of this class of machinery, and whose labours have been attended with practical success, is Mr. Alexander Wylie, of the firm of John Wilson and Son, Johnstone, near Glasgow. A general view showing the arrangement of a lead-pipe press and accessories as made by this firm, is shown at Fig. 2. Not only is this press available for the manufacture of the ordinary lead and composition pipes, but for producing block tin lined lead pipes, as well as lead bullet rods, and for covering telegraph cables.

On reference to Fig. 2, the apparatus will be seen to consist of an hydraulic cylinder at the base, with a ram and crosshead, having a central opening and supported by four columns which are carried by the hydraulic cylinder. Supported on the ram is a removable lead container, whilst to the crosshead is fixed a plunger, within which a die is fitted for forming the outside of the pipe. The core, or mandrel, for forming the inside of the pipe, is fixed in the centre of the container, or a crossbridge core and die combined is fixed in the point of the lead ram for small pipes. The molten lead is run from the melting-pot, seen on the right of the press, to the container, and after it has been filled the charge is allowed to remain until it has reached a temperature of about 400° F., when it will have become plastic. The hydraulic ram is then forced up at a pressure of from 15 to 35 cwt. per square inch (according to the size of the pipes produced) raising the container and pressing the surface of the metal against the lead ram and the die. The lead is thus forced out through the annular space between the core and the die, producing a continuous length of pipe. When the charge of lead in the container has been exhausted, the hydraulic return motion in connection with the pumps is put in operation and the container descends to its original position. In the interior of the hydraulic ram is a small intermediate ram for the purpose of rapidly changing the cores and dies for making different sized pipes, without removing the container, a process causing delay, but which is necessary under the old system. A safety automatic stop motion, seen on the right-hand column of the framing, is provided, being actuated by the container when it has travelled the desired distance. By this means the bottom valve of the hydraulic cylinder is opened, and the water escapes thence to the cistern. At the right-hand bottom corner of Fig. 2 is a detail of the hydraulic piston. The hydraulic pumps are sometimes driven by a vertical engine, as shown in Fig. 2, and sometimes by a horizontal engine seen at Fig. 3, the one or the other being supplied at the option of the user; both, however, are equally convenient. The mechanism for actuating the return motion by hand is seen to the left of the press, just above the line of pipe passing from the press to the coiler, whilst on the right is a crane for lifting the container to and from the stove where it is warmed up before receiving the first charge when starting to work after a long stoppage.

In a later arrangement the old hand crane and stove for heating the container are dispensed with. The container is now steam-jacketed, and is heated up by steam to the required temperature in ten minutes without being removed from the machine. This is a great improvement and one which is appreciated, many old containers having been converted on the new principle.

There is, however, work still left for a crane in changing the containers and rams to suit the various sizes of pipes. For working a lead press Messrs. Wilson employ three containers, one of which makes pipes from $\frac{1}{8}$ inch to 1 inch diameter, a second being used for pipes up to 2 inches diameter, whilst for pipes up to 6 inches or 8 inches diameter a third container is supplied. These containers are interchangeable and an hydraulic crane is employed for doing this work. The crane is worked by regulating valves from the hydraulic pumps which serve the press.

Encasing Telegraph Cables.

Before leaving the subject of lead pipe manufacture it will be interesting to notice the application of the extrusion principle to the production of lead pipe for encasing telegraph cables. Put correctly perhaps this process should be called the covering of electric telegraph cables with lead. All the same, it involves the manufacture of a continuous length of lead pipe. In the early days of electric telegraphy numerous methods of encasing conductors in lead were devised, but only a few were adopted. One of these few consisted in fastening one end of the conductor to be covered to the end of the core in the press in which lead pipe was made, the core being somewhat larger in diameter than the cable to be covered. The conductor was laid out on a long bench having conveying rollers placed at intervals along its surface, and as the pipe was forced out it travelled along, encasing loosely the conductor. When the length of cable laid out was covered, the end next to the press was cut off and the lead pipe formed was tightened on the cable either by being passed through a die or between rollers.

This system had many drawbacks. It was both slow and cumbersome, and only comparatively short lengths of cables could be covered, necessitating frequent jointing and consequent increased risk of failure of the cable at these points. The lead pipe was made at a temperature of nearly 400° F., which generally destroyed the insulating material and rendered the cable useless. A slight improvement was effected by attaching the cable to the core of the lead press by a length of wire. It was thus possible to pass the lead pipe through a trough of water, and to cool the outside before it reached the cable. But even with this improvement the process had only a limited application. It was also a common practice for cable manufacturers to purchase lead pipes and draw the cable to be protected through them, tightening them by means of rollers or a die.

Telegraph Cable Covering Press.

Through the rapid development of the numerous practical applications of electricity, however, an efficient means of covering cables with lead soon became a serious want. But it was a want not easily satisfied, inasmuch as to meet it efficiently demanded compliance with several difficult conditions. In the first place the lead covering had to be made of any required length without a joint. In the next the tube had to be concentric and put on the cable in such a way as neither to fit too loosely nor to compress the cable, and thus impair the efficiency of the insulating material. It was also necessary that the cable should not take so long in its passage through the lead press that the high temperature of the press damaged the insulating material. All these conditions had to be fulfilled by a machine which would work at a rate of speed and cost, approximating to the speed and cost at which ordinary lead pipes were made. Through the ingenuity and perseverance of Mr. Wylie all these difficulties were overcome, and an important want was supplied in the press illustrated at Fig. 4, which is specially applicable for covering cables with a lead tube of any desired thickness. The leading feature of the press is that the cable after being finished and insulated is passed horizontally through a hollow core and the die. The cores and dies are easily interchangeable, and the cable manufacturer usually has a complete set for cables of different diameters and different thicknesses of lead. The arrangement of the core protects the cable from the pressure which is necessary to force the lead on to the cable, and the lead tube can be made to fit tightly or slackly as may be desired. Referring to Fig. 4, *a* is the container; *b* the plunger; *c* the cellular base with water chambers; *f* the two-part core and die-seat; *g* the regulating die; and *h* the conical guide.

The container is filled with lead to be operated upon by either a hollow plunger for ordinary lead pipes or by a solid plunger for electric wires and cables. In order to prevent the cables from being injured by heat, water chambers, as shown, are provided, allowing of a continuous circulation of cold water round the hollow block through which the cable passes. The ring or dies requisite for regulating the thickness of covering are placed in the hollow block, and the guiding cores are secured to the container by regulating screws. These guiding cores are either hollow or double cased to allow of the flow of cold water. To prevent the metal passing through the side of the hollow block, the core is screwed up against the regulating ring or die, the cable is passed through the core, and when the metal is solidified in the first charge the core is unscrewed back as desired to allow the metal to pass round and cover the cable. By this means the cable is only exposed at the point of contact, a feature of the first importance. The successful working of these cable-covering machines is evidenced by their extensive adoption by cable manufacturers.

DICK'S EXTRUSION PROCESS.

In his opening remarks, the author referred to the circumstance that the flow of metal had in the past formed a subject of study with scientists, and that the outcome of their studies had proved of practical value to metallurgists. Among others who have studied that interesting subject, and who have reaped practical benefit therefrom, is Mr. Alexander Dick, to whom the author has already alluded. The line of investigation and research followed by that gentleman had reference to the flow of metals at high temperatures through orifices under pressure. His investigations led him to the conclusion that he was on the track of a new and improved method of manufacturing rods, bars and tubes which were ordinarily produced by rolling or drawing. He also anticipated the opening up of a new field of industrial departure, in the production of bars of the most complex sections and such as could not possibly be produced by rolling, nor indeed in any other way except at great cost. He carried out a long series of experiments which were based upon the principle involved in the lead-pipe press. Endeavours had already been made to adapt this principle to the manufacture of copper and brass rods, but without success.

Three very difficult problems presented themselves for solution at the outset. The first was, how to maintain the temperature required to keep the metal in the precise condition of plasticity that was necessary for the operation to be successful; the second was, how to construct a container of sufficient strength to resist the necessary working pressure with its contents at that temperature; whilst the third was, how to prevent the backflow of the plastic metal in a direction opposite to the die. There were also other questions of detail which had to be answered before success was attained, such as how to get rid of the fag-end of a charge after pressing; but the three main difficulties by which Mr. Dick was confronted were those just stated. By dogged perseverance however, he in time overcame them all.

THE CONTAINER.

In designing the container it had to be borne in mind that iron and steel lose much of their strength when heated to redness—cast iron as much as two-thirds, and wrought iron and steel about one-third—and that when the temperature is still further raised the loss becomes increasingly greater. The working temperature of the metals and alloys with which

Mr. Dick experimented, ranged from 800° to 900° F., at which temperatures steel retains only about thirty per cent. of its original strength. It was, therefore, clear that an iron or a steel vessel which was to contain the plastic metal would not be sufficiently strong to resist the internal pressure necessary to cause the charge to flow through the small orifice of the die.

At the outset of his experiments Mr. Dick had several cylinders made, some of wrought and some of cast steel, with the object of ascertaining which was best suited for the container. The cylinders were 24 inches long and 6 inches diameter internally, the walls varying in thickness from 3 to 6 inches. In order to maintain the plasticity of the metal during the operation of pressing, an annular chamber was formed around the cylinder in which was a coke fire. Success, however, was not yet attained, for owing to the strains set up by the unequal expansion and contraction of the walls of the cylinders, added to the internal working pressure, they soon cracked and were rendered unserviceable. Not one of the cylinders would stand more than three tons per square inch at the working temperature, Delta metal being the material operated with.

But "Hope springs eternal in th' inventor's breast," and so in spite of repeated failure Mr. Dick remained undaunted, and set to work to devise other means whereby he hoped to accomplish his end. Experimenting in a different direction he at length succeeded in overcoming the difficulty caused by temperature and pressure in the chamber by constructing a composite container. Instead of being solid, the wall of the container was divided up into sections with spaces packed with a dense non-conducting material. The principle underlying this arrangement is that, whilst steel, when heated to a high temperature, loses its integral strength, yet at lower temperatures it retains its full power of resistance to pressure. Thus a chamber composed of several comparatively thin walls and protected from extreme heat, will resist pressure better than a chamber having a thick solid wall heated to a higher temperature.

This composite system of construction enables the liner, which is exposed to the extreme heat of the metal, to be made with a comparatively thin wall, and it is not liable to be fractured by the expansion and contraction arising from unequal heating and cooling. It is, moreover, reinforced by the surrounding steel parts which, although themselves thin, are insulated and supported by a dense packing of non-conducting material. They are thus kept at a comparatively low temperature, and in a condition to offer a maximum of resistance to the central pressure, and this condition is further mechanically influenced by a stout outer casing of steel.

The Apparatus.

By the courtesy of Mr. Dick the author has been afforded several opportunities of inspecting the apparatus and of witnessing its operation at the Delta Metal Works, Pomeroy Street, New Cross, London. Two perspective views of the apparatus are shown in Figs. 5 and 6, Fig. 5 being taken from the front end, and Fig. 6 from the rear end of the machine. It is 16 feet long by 6 feet wide, and 5 feet high over all. It consists mainly of the compressing cylinder or container and the hydraulic ram. The container has an inner liner of cast steel, the internal diameter of which varies in different containers according as to whether they are required for pressing light or heavy charges, the container being changed as required. The container is mounted on trunnions similarly to a Bessemer converter, and is fitted with worm-gearing for bringing it to the vertical position for being charged with metal and for restoring it to the horizontal for the operation of pressing.

The die-plates are formed with either a single opening or with several openings, each one being of the section required to be given to the article to be produced. The openings may be all of the same section or they may be of varying sections if required. The die-plate is mounted in a holder in which it is easily fixed, and from which it is as easily removed when changing for the production of different sections. In order to prevent chilling the metal, the die and its holder are heated. The die is fitted into a shouldered recess in the holder, which is coned to seat into a hollow metal block. This block is held firmly in position during the operation of pressing by a pair of gripping jaws actuated by hydraulic power. The die-holder and the gripping jaws are carried in a strong crosshead as seen in Figs. 5 and 6, in which the die-holder and its adjuncts, together with several dies as well as a container, are also seen.

The Products.

The primary application of this system of expelling heated metal under pressure was to the production of solid rods and bars. In course of time, however, Mr. Dick made the important discovery that copper and its alloys in a heated and plastic condition could be separated, and that the surfaces would re-unite by simple pressure provided that air was excluded and that they remained unoxidised. Under these conditions a true weld is formed which it has been found impossible to rupture. A singular verification of the circumstance that by preventing the access of air to the separated portions of the metal, they will re-unite, is shown by the fact that for a few inches at the front end of every extruded tube the metal never re-unites, as will be seen on reference to Fig. 7, and to the actual tube on the table. It may be thought that this separation is due to the cooling action of the die on the metal. As, however, the die is previously heated, this is not the case. The initial severance of the metal is solely due to the presence of air in the die, and its subsequent re-union to its absence. This important discovery underlies Mr. Dick's system of producing metallic tubes of any section by the same process as that employed for producing solid sections. The production of both bars and tubes is carried on by means of the same apparatus, the only difference being the form of the die.

Method of Working.

The author has seen Mr. Dick's press running both on solid complex sections and on tubes. The method of working, which is similar in both cases, is as follows :—The opening at the front end of the container, through which a charge has just been expelled, is first closed and the container is turned into a vertical position. A fresh charge of metal is then placed in the container, and when the required degree of plasticity has been reached, a check disc for preventing back-flow is placed on the top of the metal. The container is then returned to the horizontal position, the stop-plate removed, the hydraulic pump started, and the charge expelled in the form of rods or tubes as the case may be. The stump, or remainder of the charge, is subsequently pushed out of the container by the ram, the rods or tubes cut off, and the container made ready for a fresh charge. Some idea of the difficult and complex sections of bars produced will be gathered from Fig. 8, as well as from an inspection of the specimens on the table. The same remarks apply to the tubes, sections of which are seen at Fig. 9, and on the table. The specimens exhibited have not been touched since they left the dies, and it will be seen that the surfaces are perfectly smooth and require no further finish.

Physical Characteristics of Extruded Metal.

Metallic bars produced by extrusion present several special physical characteristics which the author deems sufficiently interesting to notice as being an outcome of Mr. Dick's process. In the first place, owing to the great pressure put upon the metal, its quality must obviously be greatly improved, in the same way that Whitworth steel is improved by compression. It is found to be of greater density and perfectly homogeneous. The actual increase of strength in extruded bars over that of hot rolled bars of the same metal, varies with the nature and composition of the metal or alloy. Taking ordinary yellow metal, the increase in tensile strength is 24 per cent,, with a proportionate increase in elongation. Some tests made at Woolwich Arsenal with Delta metal bars produced by extrusion, show a tensile strength of 48 tons per square inch, with 32·5 per cent. elongation on two inches, against 38 tons per square inch tensile strength, and 20 per cent. elongation of hot rolled bars of the same metal.

Still more noteworthy is the behaviour of extruded metal under the turning tool, and in the screwing machine, as it can be worked with equally excellent results at ordinary speeds, or at speeds from three to four times greater than those at which rolled or drawn brass can be worked. The results thus obtained appeared to the author so remarkable, that he proposed to take steps to verify them, for which Mr. Dick readily gave permission. A series of tests were therefore made for the author with extruded metal, by Alfred Herbert, Limited, of Coventry, on one of their Hexagon Turret Lathes. The particulars and results of these tests are tabulated in the accompanying statement, whilst the specimens tested and the tool with which the whole of the straight work was performed are on the table.

The results of these tests show that an unlimited cutting speed can be maintained on extruded metal without deteriorating the value of the article being manufactured as regards accuracy of dimensions and quality of work. The condition of the cutting tool with which the whole of the parallel work of the eight specimens was machined will be seen to bear out this statement, as it was not ground once during the testing operations. The author would direct attention to the test of specimen No. 5, in which it will be seen that a reduction from 1 inch to ⅜ inch was made in two minutes at a cutting speed of 355 revolutions per minute, with 1 inch feed in 8 seconds, the specimen being reduced down in one cut. This is a very fine example of work, and one which proves the tenacity of the metal under such a great strain. Ordinary rolled or drawn brass worked under similar conditions would either twist or break off. It will also be noticed that the threads of the screwed specimens are exceedingly fine; they were likewise screwed up in one cut.

STATEMENT SHOWING RESULTS OF TESTS OF EXTRUDED BRASS BARS.

Number of Specimen.	Diam. and Shape of Extruded Brass Bar.	Reduced to	Length.	Revolutions per Minute.	Feed.	Total Time taken.	Remarks.
					in. secs.	min. secs.	
1	2 in. round bar	1¼ in. and ⅞ in. diam.	9¾ in.	282	1 in 20	5 45	
2	Hexagon, 1½ in. over flats.	⅞ in. diam.	7 in. inside head.	282	1 „ 20	4 7	See remarks on Specimen No. 7.
3	1½ in. round bar	½ in. diam. in smallest part.	12 in.	282	1 „ 20	6 4	Forming done at same speed with a plentiful supply of lubricant.
4	Hexagon, 1⅛ in. over flats.	⅝ in. diam.	5 in.	355	1 „ 17	3 4	
5	1 in. round bar	⅜ in. diam.	10⅜ in.	355	1 „ 8	2 0	
6	Hexagon, 1⅛ in. over flats.	⅝ in. diam.	5 in.	355	1 „ 8	1 50	
7	Hexagon, 1½ in. over flats.	⅞ in. diam.	7 in. inside head.	355	1 „ 8	2 45	This specimen is of exactly the same dimensions as No. 2, but was taken with a considerably higher cutting speed and a feed 2½ times faster. The result is practically the same, and it clearly shows that the machine tool can be run on this metal to its highest possible speed. Ordinary lathes are not provided with speeds sufficiently fast to dull the tools when turning this metal, and the lathe spindles cannot be run on sufficiently high speeds to do this work without causing trouble with the lathe bearings.
8	1⅜ in. round bar	⅞ in. diam.	8 in.	355	1 „ 8	2 45	

In fact, the whole of the samples were taken down from the original to the smallest reduced diameter in a single cut, which speaks equally well for the metal and the machine upon which it was tested. Not the least important advantage accruing to users of the metal is the great saving in time which results, the work being performed in something like one-third the time required for ordinary rolled or drawn metal.

High as are the speeds given in Alfred Herbert's tests, the author is informed by the Delta Metal Company that they have been considerably exceeded by some users of the extruded metal, speeds of even 700 to 800 revolutions per minute being found practicable on 1-inch rods in plain work. As an example it is stated that one firm reduce $1\frac{1}{16}$-inch extruded brass to $\frac{3}{4}$-inch at one cut, running at a speed of 600 revolutions per minute. The turning tool cuts from the side, and is fed up to the end of the rod; that is to say, the tool is not pushed dead on to the front of the rod as in the case of an ordinary forming tool. It is clear then that, from a commercial point of view, the question of working speed constitutes an important factor in the successful manipulation of extruded metal.

The following particulars relate to work performed on some specimens of Dick's extruded brass, the specimens, which are on the table, having been machined by White and Poppe, Limited, of Coventry.

No. 1 shows a screwed cap to fit into the body of a fuse, the cap being $1\frac{1}{4}$ inch in diameter over all by $\frac{13}{16}$ inch diameter over the screwed portion, which is $\frac{1}{4}$ inch in length. The cap was made in 45 seconds at a speed of 1000 revolutions per minute.

Nos. 2, 3 and 4 show a screwed plug in various stages of completion. The plug is made from $1\frac{3}{4}$-inch rod, specimen No. 2 having been turned down to $\frac{3}{4}$ inch over a length of $1\frac{1}{2}$ inch at a speed of 520 revolutions per minute in 9 seconds at one cut.

No. 3 shows an advance upon No. 2 in having the original diameter reduced over a length of 1 inch to $1\frac{1}{8}$ inch diameter, and in being bored out $1\frac{1}{16}$ inch deep by $\frac{13}{16}$ inch diameter with an internal screw cut $\frac{1}{4}$ inch deep, the whole of the work having been done in 24 seconds at 520 revolutions per minute.

No. 4 shows the completed plug, the outside screwing $1\frac{1}{8}$ inch diameter by 1 inch long, and $\frac{1}{2}$ inch diameter by $\frac{1}{4}$ inch long, having been done in 45 seconds, besides which a number of small holes were drilled at varying angles and positions in 85 seconds.

No. 5 is the firing mechanism of a time fuse, the whole of the drilling of the body having been performed in 15 seconds.

No. 6 is a set of small discs $\frac{1}{4}$ inch diameter by $\frac{3}{32}$ inch thick, with a $\frac{3}{32}$ inch hole drilled through the centre and the outer edge of the disc screwed. The discs were finished at the rate of 7 per minute and at a speed of 4000 revolutions per minute.

No. 7 is a screwed stud; the head is $\frac{9}{16}$ inch diameter and the screwed portion $\frac{3}{8}$ inch diameter by $\frac{3}{16}$ inch long. The head, which is $\frac{1}{16}$ inch thick, is bevelled. The whole of the turning and screwing was done at 500 revolutions per minute.

Nos. 8 and 9 are two specimens of extruded brass rod $2\frac{3}{8}$ inches diameter reduced over a length of $2\frac{1}{2}$ inches to $1\frac{3}{8}$ inch diameter at one cut at the rate of 900 revolutions per minute; progression of cut 45 revolutions to the inch.

CONCLUSION.

The author has now taken the members back about two thousand years, to the earliest form of metallic pipe of which he has any personal knowledge, namely, the primitive lead pipe of the Romans. Coming down to later times, he has noticed the early manufacture of lead pipes by rolling and drawing, and the supercession of those imperfect processes by the press which has been so greatly improved upon by Mr. Wylie. Finally he has described Mr. Dick's unique extrusion process and its remarkable products, and he now leaves the matter in the hands of the members in the hope that, in discussing the subject, they may be able to add to the information contained in the paper. His concluding words must be those of thanks to those gentlemen who have kindly afforded him various particulars which have been of much service to him in the preparation of his paper, and who have lent him the numerous specimens of work exhibited.

DISCUSSION.

The PRESIDENT said that he was sure they would all agree in according Mr. Nursey a very hearty vote of thanks for his exceedingly interesting paper. Mr. Nursey had read a great many papers before the Society; he believed that they numbered twenty-two, the first being given in 1860. Mr. Nursey had gone into the subject in a highly commendable way; and the interesting specimens which he exhibited showed that he had entered into the spirit of the paper as thoroughly as he entered into every thing that he did. He should like to ask Mr. Nursey how the temperature of the metal and the exact degree of plasticity was ascertained and regulated during the time that extrusion was going on. It seemed to him that there might be some difficulty in ascertaining the required point of plasticity of the metal in the container. Another point was, supposing, in the case of lead pipes, that the quantity of metal ran short before the proper length of pipe was completed, and the container had to be refilled, would there be any difficulty in making a joint between the pipes formed by the two charges of metal ? As to the Roman pipe, he presumed that the joint was made in that case by heating.

The vote of thanks to the author was carried by acclamation.

The President then asked Mr. Chatterton to open the discussion upon the paper.

Mr. GEORGE J. CHATTERTON said that, in the absence of Mr. Wylie, he had reluctantly consented to open the discussion. The paper referred to a very intricate process; and he was sure that the discussion would be a great deal safer in the hands of professional engineers. As for himself, he was only a pipemaker, who represented the extrusion of lead and block tin through dies, although he used Messrs. Wilson's presses at his works.

Mr. Nursey had certainly taken a very big jump from the time of the Romans to that of Wilkinson, who, in the year 1735, made his fortune by producing lead pipe by the process which Mr. Nursey had so well described in the paper, namely, the casting of a short cylindrical ingot of lead encircling a core or mandrel, and passing it through rollers or drawing it through dies. The length of the cores used by Wilkinson was about 15 feet for a 1 inch pipe; 12 feet for over 1 inch up to 2 inches; and 10 feet for anything larger. The strength of the various lead pipes produced was estimated by the number of pounds per length; that was to say a 15 feet length of ¾-inch pipe would weigh so many pounds, and after 1 inch was arrived at the pipes would be regulated by 12 or 10 feet lengths, as the case might be; not by the yard, but by the length of the pipe as it left Wilkinson's apparatus. Such was the conservatism of the British workman that those lengths were in use at the present day, at all events in London; and although he (Mr. Chatterton) had tried very hard to get the trade to order lead pipes by the weight per yard, or foot, or whatever the unit might be, they still persisted in ordering by the 12 feet, or 15 feet, or 10 feet length. It would be a very good thing if they could get one unit for all sizes of pipes; and he hoped that that unit would belong to the metric system.

The paper showed a very favourable application of the immense power which was placed at their disposal by the hydraulic press. The "hydrostatic paradox," as it was called, which was given to the world by Pascal, became, in the hands of Bramah, the hydraulic press. It was an instance of what was formerly a philosophical toy becoming a practical machine at the disposal of the engineer. It was obvious that somebody had made use of that power by putting Wilkinson's cylindrical ingot into a cylinder and applying pressure instead of passing it through rollers. A press was patented by Mr. Burr, of Shrewsbury, in 1820. The material of which the container was made was very much like cast iron, and there was no liner. Mr. Burr had very great trouble, when he got the enormous Bramah press at work, to control the force that he had at his disposal, and the containers therefore frequently broke. Then it occurred to some one to fit a liner of tougher material inside the container, made in the following manner:—Wrought-iron washers were forged and welded one on the top of another until the proper length was got. The result was that they were very much like an earthworm in construction, and were apt to part at the weldings. Then steel came to the front, and now they could make an ordinary container to stand the pressure applied to it.

The modern process of lead pipe-making had been very properly described by the Americans as squirting. It was evident that before one atom could extrude through the die the whole charge must be brought into motion. Then it occurred to a brilliant mechanic named Weems, of Johnstone near Glasgow, the predecessor of Messrs. John Wilson and Son, about the year 1852, to insert a hollow cylindrical piston at the top of the charge instead of a solid one at the bottom. The charge was brought up by means of the hydraulic press and extruded as in Mr. Wylie's press. The object of that was to minimise pressure. The effect was to produce lead pipe at a less expenditure of force than had hitherto been possible.

It would be found in all these processes that the pipe exuded in the axis of the ram, and probably the limited time at Mr. Nursey's disposal had caused him to curtail his description of the next invention, which was to make the pipe exude at right angles to the ram. In Mr. Wylie's cabling press, as the author had stated, the pipe came out at right angles to the piston, and by that means Mr. Wylie was able to produce a continuous length of pipe, and to insert therein the cable which formed an important item of improvement in the mechanics of to-day. The Americans had also adopted the principle of making the lead pipe exude at right angles to the force employed.

In the manufacture of curved lead traps there were two charges of lead and two pistons moving opposite to one another. The two charges were pressed towards each other, and, so long as the two pistons were kept absolutely at the same speed, the lead pipe exuded in a straight length. But, if one of the pistons moved more quickly than the other, the lead pipe, instead of coming straight up, had a bend over to one side, and consequently a very elaborate method of regulating the relative speeds of the pistons was invented. The effect of that was that the pipe, instead of being allowed to come straight up, could be made to go up and down and up again, and thus brought to any desired curve.

With regard to the ordinary lead pipe press which was shown at Fig. 1 in the paper, the pipe was continuous as long as there was any lead in the container; but there was no means of making it of infinite length. As soon as a charge was exhausted another charge had to be put in and there was a break of continuity. But the improved process which Herr Krupp, Mr. Wylie, and others had invented, afforded a means of putting hot lead in and burning it, as it were, to the stump end of the old charge, and then applying pressure and making a continuous length of pipe. It would not be possible to cover a cable with lead unless some such process was at their disposal. He therefore ventured to correct the impression which appeared to exist that a continuous length of pipe could be made by the older presses.

If he, as a lead pipe manufacturer, might venture to further criticise such an able paper, he would point out that there was a technical statement that might perhaps be amended. The author said, "In the interior of Mr. Wylie's hydraulic ram is a small intermediate ram for the purpose of rapidly changing the cores and dies for making different sized pipes without removing the container, a process causing delay, but which is necessary under the old system." This intermediate ram is to assist in changing the cores only, and has no connection with the dies.

Coming to Mr. Dick's valuable, or, he might say, invaluable process, and to the metal which he was able to treat so well, he had very little to say, because that was more an engineering than a pipe-maker's matter. He would, however, observe that the author said, "Not one of the cylinders would stand more than three tons per square inch at the working temperature, Delta metal being the material operated with." He (Mr. Chatterton) did not quite understand that. He thought that what was meant was that, presuming that Mr. Dick used a 20-inch water ram, he would have at his disposal, in round numbers, 300 square inches of ram surface, and if he applied 3 tons to the square inch he would get something like 900 tons;

and so he supposed that the statement wanted correcting in this way, viz. that not one of the ordinary steel containers would resist the force generated by more than 3 tons per square inch on the water ram.

The present was not the first occasion on which the world had been enlightened by Mr. Nursey on the subject of this very interesting process. Some years ago, when he was publicly referring to the subject, he expressed a hope that, as a result of further improvements in the resisting properties of steel, Mr. Dick would be able to deal with not only Delta metal but steel itself. He should like to ask Mr. Nursey whether he was in a position to give them any hope that they would ever be able to get extruded steel bars of various sections.

During his business career he had endeavoured to get hold of some of the best apparatus for such processes as those with which the paper dealt, and he thought that in the press as improved by Mr. Wylie they had as good a system as any in the market. But still the Germans had not been idle in the matter. There was a press not referred to by Mr. Nursey made by Herr Krupp. There were two cylinders for the lead and two pistons pushing in opposite directions precisely as in the trap-forming press to which he had alluded. As the lead exuded a hollow mandrel protected the cable and formed the enveloping tube. The process was in use in Germany and also in England. It worked very well, but he did not say that it was any better than Mr. Wylie's; and he was told that the machine was a very expensive one. He thought that the principle of making lead and other materials into tubes at right angles to the force employed was one of the things which they must think of in future, but of course it took an enormous amount of force to make lead turn a corner. The inventions which they now had, the materials already at their disposal and the inventiveness of the chemist were such as to lead to the hope that they would be able to go on from time to time to stronger and still stronger materials, and that they would be able to apply still more directly the virtually unlimited force which they had at their fingers' ends in the hydraulic press.

Mr. HENRY SHERLEY-PRICE said that he thought a little mistake had been made by the author about the so-called marvellous speed of turning soft brass or soft metal. A thousand revolutions a minute was not a very great speed. It would be found every day in Birmingham, and even 1200 revolutions a minute would be met with in turning soft metal; but he certainly was struck with astonishment when he was told that certain of the samples shown were done at one cut. His astonishment was not at the speed but at the depth of the cut; and of course that practically regulated the speed.

In going through engineers' works in this country and abroad he constantly came across Delta metal, and he knew the material by repute; but he had never seen the process of tube-making by extrusion applied to such hard metal as was found in the samples on the table.

With regard to the hydraulic pressure which Mr. Chatterton had referred to, namely 1000 tons, he (Mr. Sherley-Price) called that small. At Armstrong's a pressure of several thousand tons would be found. As might be imagined, the entire press was all constructed of forged steel. Such presses were becoming quite common, and they would be found at Armstrong-Whitworth's, Vickers', Firth's, Krupp's, and most of the big steel factories.

Mr. Chatterton said that, in speaking of the pressure, he was referring to the container.

Mr. Sherley-Price said that he had understood Mr. Chatterton to be referring to the enormous total pressure of the metal when he said that probably no press would stand the pressure. The mere fact of a thousand tons pressure over an hydraulic press for the mere purposes of forging was common now.

Mr. Thomas Woof said that Mr. Sherley-Price had referred to soft metal being cut at a speed of a thousand revolutions a minute, and in some cases even higher. That, together with his (the speaker's) experience, and the experiments recently carried out by Messrs. Herbert, clearly proved that unlimited cutting speed could be obtained with Dick's extruded metal. He saw, a few days ago, threads chased on metal 1¼ inches in diameter, running at 500 revolutions per minute. A few years ago it would have been thought that there was some magic or mystery in cutting metal at anything approaching these speeds.

The only question involved was in obtaining machinery where due attention had been given to the bearings, to allow the machines to run at the high speeds required in modern practice. With reference to specimen No. 5, that was, without doubt, a very fine sample, and showed both the metal and the machine to great advantage. That sample was reduced from 1 inch diameter to ⅜-inch by 10⅜ inches long in one cut, at a feed traverse of 1 inch in 8 seconds, the cutting tool in that instance was operated from the chuck securing the bar, the feed traverse being reversed. There was no difficulty in screwing extruded metal, as compared with other metals; the only precaution necessary was to have a plentiful supply of lubricant, otherwise the threads in screwing would have a tendency to be rough.

Mr. H. Holttum said that he had been much instructed by the paper that evening While the discussion had been going on as to the strength of the containers and the strain upon them, it had struck him that the die might claim similar consideration. He should like to know how long the die lasted in lead extrusion. Did the die suffer severely when it was used for the extrusion of Delta metal (samples of which he saw lying upon the table), and could anyone tell him in what way the die suffered?

Mr. Joseph Bernays said that he had not had any practical experience in connection with Mr. Dick's process, but he had had a great deal to do with lead pipe press construction, and he could answer Mr. Holttum's question about the dies. When used for lead they lasted a very long time indeed; but for Mr. Dick's metal he could not say how long they would last. He had hoped that some one connected with the Dick extrusion process would be present and would give his experiences, for after all, Mr. Nursey's paper, though extremely interesting, and showing a great deal of investigation, had left them rather in the dark upon the details of that particular process. Mr. Nursey had clearly stated that the success of the process really depended upon details, and that was what the paper ran somewhat short of. The mere pressing of materials through dies was very old, and it had been used for all sorts of materials. He would ask Mr. Nursey whether he could not give them a little more detail. They had had nothing but the general views of the machinery. Mr. Nursey, in speaking of the method of working in Mr. Dick's process, spoke of a check disc. He (Mr. Bernays) would very much like to know how the check disc was applied, and what it was applied for. Was it to be kept in place until the metal was cool, or was it merely used whilst the metal was in a molten condition? He would like to call attention to some extraordinary sections of Dick's metal on the table. One would hardly think it possible that they could have been produced by extrusion.

Mr. Chatterton, junr., said that Mr. Sherley-Price had observed that a thousand revolutions a minute was common, and Mr. Woof had said that 500 revolutions was common for screw-cutting. That might be; but he should like to know what the peripheral speed was. The peripheral speed was the important thing to know, and not the number of revolutions per minute.

Mr. Sherley-Price said that, of course Mr. Chatterton was quite right with regard to peripheral speed. They would not attempt to compare a three-inch bar with a one-inch bar. If they did they would come to grief. But he saw a sample finished at three-eighths which began at one and a quarter inch. The difference of peripheral speed in that case would not be sufficient to make very many revolutions difference. But the three-inch diameter would, of course, make a considerable difference. They could not go at the same speed with a three-inch bar as with a three-eighths inch one. That went without saying. But that was by no means the limit; 1200 revolutions, perhaps, was not common; but it was not uncommon with soft yellow metal with anything up to about one inch for light turning. When they got beyond that, of course, they reduced the speed. He was not speaking of chasing screws. He was merely speaking of turning soft brass light rods and such like articles.

Mr. Nursey, in replying first to the President's inquiry as to how the temperature of plasticity was known, said that it was left to the judgment of the foreman at the press. The metal was charged into the container at a given temperature, and the foreman allowed a certain time for it to acquire plasticity. In the case of Delta metal it was sometimes charged into the container in a state of plasticity and sometimes in the molten state. The foreman soon acquired proficiency in fixing the point of plasticity.

With regard to re-charging the container of the ordinary pipe press, the charge was always that required for a given length of pipe, or rather slightly in excess. He was sorry that Mr. Wylie was not present, as he alone could answer many of the questions that had been asked. He saw Mr. Wylie last week and knew that he intended to be present; but three days ago Mr. Wylie informed him that he was prevented being present owing to other engagements. He was equally sorry that Mr. Dick was not present. Mr. Dick fully intended to be present, but he had been called away to the Continent on pressing business.

He (Mr. Nursey) was personally obliged to Mr. Chatterton for the interesting information which he, as a manufacturer, had been able to place before the meeting on the subject of the paper. Mr. Chatterton, however, had stated that, owing to the conservatism of the British workman, lead pipes were only manufactured in 10 or 12 feet lengths in London. At Messrs. Pontifex's works, in the city of London, pipes were made in 60 feet lengths, as he (Mr. Nursey) had seen and had stated in his paper. With regard to the statement in the paper respecting the pressure exerted in Mr. Dick's experimental cylinders, it should be the pressure on the ram as Mr. Chatterton had pointed out.

Mr. Chatterton had kindly put an excuse into his (the author's) mouth for the absence of details respecting Mr. Wylie's cable press, and had asked questions with regard to certain statements made in the paper. The whole of the statements relating to Mr. Wylie's presses—both the pipe and the cable presses—were made upon information obtained direct from that gentleman. He (Mr. Nursey) felt it due to himself to state that he had experienced some difficulty in getting any detailed information from Mr. Wylie, and detailed information was everything to engineers. Mr. Wylie sent to him certain information, although in a somewhat vague form, and he (Mr. Nursey) had put it into shape, and submitted it to Mr. Wylie, and it was corrected by that gentleman and returned to the author. Every statement which was made in the paper with regard to Messrs. Wilson's presses had been passed by Mr. Wylie. He (Mr. Nursey) regretted to say that he could not clearly understand the cable press himself. He, however, depended upon Mr. Wylie's presence to clear up in the discussion that which he could not get him to make clear for the paper. Hence, both the members and himself were without the detailed information which they all desired.

With regard to Mr. Dick's process, he (the author) had stated in the paper that he had had several opportunities of seeing both bars and tubes made at the Delta metal works. He had consequently seen, and he knew, many of the details, and he would not stultify himself by saying that he did not know them. But before Mr. Dick allowed him as a friend to go over the works he asked him not to disclose any of the details of the process, and he had given his word that he would not. Mr. Wylie was probably acting on the same principle, although he had not so expressed himself. He (Mr. Nursey) thought that the members would respect the interests of those who had spent years of time and thousands of pounds, and had made good use of their brains in perfecting their respective processes. He could only say that Mr. Dick's process was the most beautiful one of the kind that he (Mr. Nursey) had ever seen.

Mr. Chatterton had referred to a paper which he (Mr. Nursey) read some years ago before the Iron and Steel Institute upon the Dick process of extrusion. That was before Mr. Dick had perfected his arrangements for producing tubes. Mr. Chatterton had said, and very properly, that in the paper to which he had alluded he (Mr. Nursey) referred to the possible extrusion of iron and steel by Mr. Dick in time. He did refer to it, saying that Mr. Dick was endeavouring to bring about that much desired result, and he also stated—which was the fact—that Mr. Dick had passed iron through his dies. But in making that statement he explained that the iron was some light thin sheet iron which had accidentally got into the metal and came out through the dies. He went on to state in that paper to which allusion had been made that it was possible that Mr. Dick might yet be successful in producing a press through which iron or even steel might be extruded; and he was supported in that view by several members of the Iron and Steel Institute, some of them being eminent metallurgists and steel manufacturers who had examined into the question for themselves, and who expressed the opinion that there was in the future a possibility of Mr. Dick succeeding. Therefore Mr. Dick might yet do it, and if Mr. Dick did it he (Mr. Nursey) would, no doubt, have the privilege of reading a paper before the Society on the subject. If he did not read a paper before the Society on the subject the members were not to conclude that Mr. Dick had not succeeded in doing it.

He thought that Mr. Price's observations had been answered by Mr. Woof. With regard to Mr. Holttum's remarks as to the life of the dies, Mr. Bernays had stated that they lasted a very long time in the lead press. The same remark would apply to the dies in Mr. Dick's press.

With regard to Mr. Bernays' question as to the check-disc in Mr. Dick's press, that detail, as explained in the paper, was employed for preventing the back-flow of the metal in the container while under pressure. It was placed on the top of the metal and came between it and the head of the hydraulic ram.

PLATE I.

THE PRODUCTION OF METALLIC BARS AND TUBES UNDER PRESSURE. BY PERRY F. NURSEY.

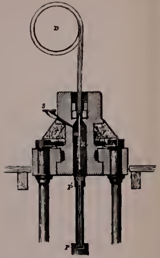


Fig. 1

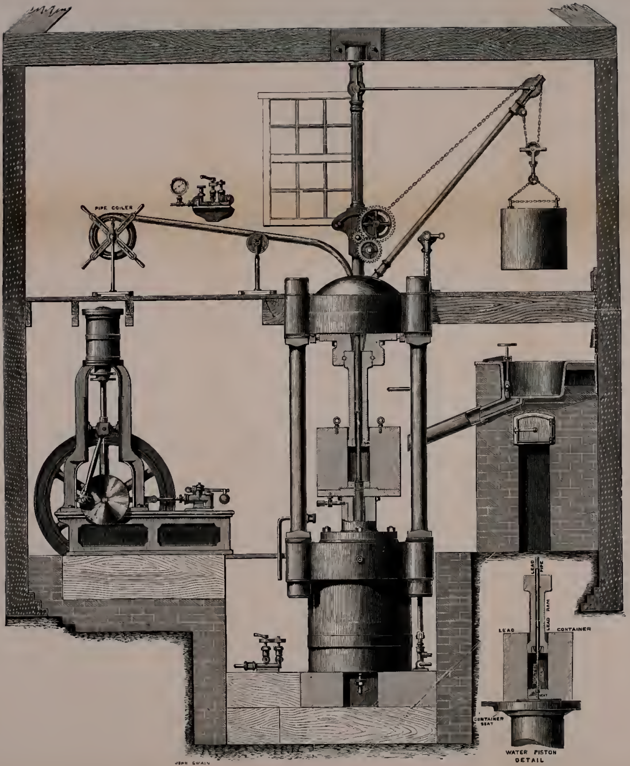


Fig. 2.

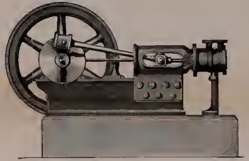


Fig. 3.

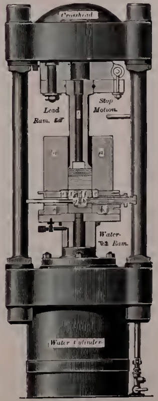


Fig. 4.

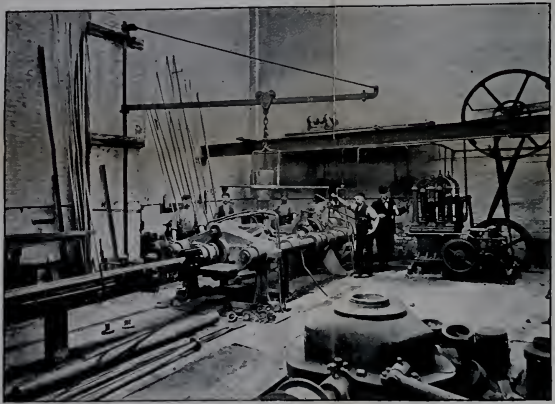


Fig. 5.

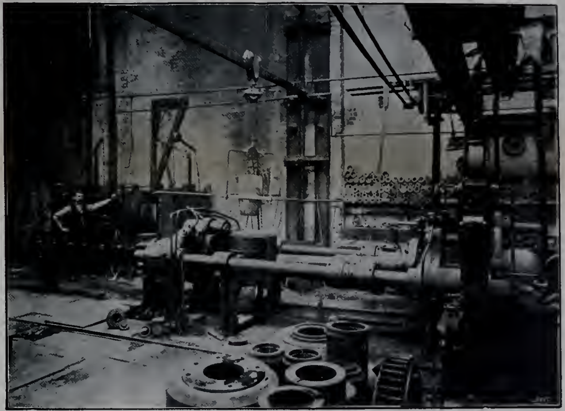


Fig. 6.

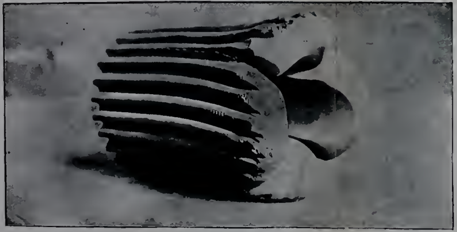


Fig. 7.

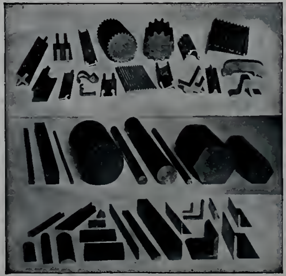


Fig. 8.

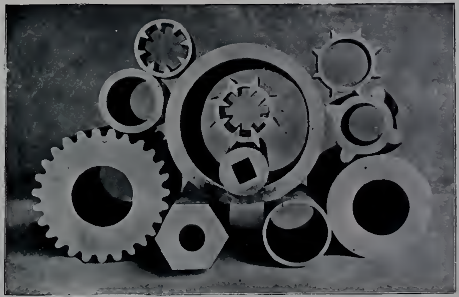


Fig. 9.

May 6th, 1901.

CHARLES MASON, PRESIDENT, IN THE CHAIR.

THE TREATMENT OF LOW-GRADE IRON ORES FOR THE SMELTING FURNACE.

By THOMAS BENJAMIN GRIERSON.

THE very serious injury which has been sustained by the British steel trade, owing, in great measure, to unlimited and unrestricted competition from other countries, will, unless steps are at once taken to prevent it, result in the steel trade of this country becoming one of the British industries of the past. The recently formed gigantic combination amongst the American steel manufacturers, points to the necessity for British steel makers to begin at once to put their works in order, and by adopting the most approved appliances known to modern science to endeavour by every means in their power to regain the high position in the world's markets which they formerly occupied, and to which their undoubted ability and experience entitle them.

The British press, with its usual foresight, "scenting the danger from afar," has focussed public opinion upon the question. The result is that many suggestions have been made, more or less valuable, in the newspapers, several distinguished individuals having taken part in the discussion, although nothing of a really practical nature has, so far, been evolved. One of the most serious difficulties as regards our export trade, with which the British steel-maker has to contend is undoubtedly that of the protective tariff, combined with the free trade of this country. The next is the want of modern appliances in British steel-works, and the most serious of all—because it is the result of the other two—is the ruinous competition between the foreign manufacturer and this country. Of England's competitors America, with her 33⅓ per cent. protective tariff on steel from this country, is undoubtedly the most to be feared. Germany comes next, but so far behind, and the conditions are so different, at any rate in degree, that we in this country may confine our attention exclusively to America.

It is, of course, not likely that American steel makers would continue to sell their goods in this country at a loss to themselves. The fact, therefore, remains that they can successfully compete with us, notwithstanding the serious drawbacks of the long overland journeys in the United States, and the voyage across the Atlantic to which their products are subject. Then, of course, Great Britain has no protective tariff to be allowed for. The inevitable conclusion, therefore, is that the American maker can produce manufactured steel at his works at a very much less cost than the British manufacturer can. Hence his success as a competitor with Great Britain.

It may be asked why it is that the American makers can do it much better than the British, who are in the great home of the iron and steel trades, with coal and ore on the very ground. One obvious answer, is that, while in steel, as in other manufactures—the engineering trades for example—the Britisher has hitherto been satisfied with antiquated, and very often extravagant, methods of working, and with old plant, the foreigner has been steadily adopting the most improved modern appliances as they have been invented, thus maintaining his works in a very high state of efficiency for economical production.

What, then, is the remedy for the unsatisfactory state of affairs now prevailing in this country? The author considers that the answer to this question is twofold. In his opinion the remedy consists in the first place in the British steel maker setting his house in order as regards improved plant and machinery and general methods of production; and, in the second place, in the utilisation of low-grade iron ores, of which there is an almost unlimited supply well within his reach, whilst other supplies are declining. Every steel maker knows that there are two classes of iron ore of high quality which are very well suited for the manufacture of steel, but which, owing to certain physical characteristics, are, *prima facie*, eminently unsuited to the requirements of the blast-furnace. These two classes are mainly low-grade magnetic iron ores which, in their normal condition, will not pay to smelt in lumps, and magnetic iron sand which, unless combined with a suitable material capable of withstanding the heat and erosion of the blast-furnace, cannot be smelted in it.

For many years past attention has been directed to rendering these two classes of ores available for the manufacture of steel, but, so far, the efforts made have been attended with only a limited amount of commercial success. The objects in view have been in the one case to crush and concentrate the lean ores, and in the other to separate the magnetic iron sand from its accompanying impurities and other undesirable constituents. By means of magnetic separators and cognate contrivances, these ends have been satisfactorily attained, but at this point another difficulty arises. In either case the resulting concentrate is generally a comparatively fine powder, which is antagonistic to satisfactory blast-furnace working, even when the concentrate is mixed with ores in masses of larger bulk, except perhaps in very small furnaces. The finely divided ore and ore-dust adhere to the wall of the furnace, causing scaffolding, that is they gradually form large masses. These masses in time become detached by the pressure of the charge above them, and being thrown down below the zone of fusion, give rise to choking and other incidental drawbacks in the region of the hearth.

In a paper by Prof. J. Wiborgh, of Stockholm, read before the Iron and Steel Institute about two years since, it is stated that there are certain conditions which modify the results of using mixtures of lump ores and concentrates in the pulverulent form in the blast-furnace. These are, the slope of the boshes and the character of the blast. The Professor instances some experiments made in 1898 in the blast-furnace at Vidlitz, in the government of Olonetz, Russia. Here the section of the furnace at the boshes was such as appears to be extremely unsuitable for the use of powdered ore. But for all this the furnace worked satisfactorily, even on concentrates alone, so long as cold blast was employed. When, however, hot blast was used scaffolding commenced and continued until the hearth and tuyeres were burnt out. Another inconvenience attending the use of powdered ores is the loss caused by dust in the gases of the blast-furnace. At Vidlitz from 8 to 10 per cent. of the powdered ore was carried over into the gas conduits. Rich concentrates have, however, been successfully smelted in combination with lump ores, as at the old works of Högfors in Sweden, as instanced by Prof. Wiborgh. At the best, however, the proportion of powdered ore that can be used in the blast-furnace is very small, and its employment at all depends upon conditions of fuel and working. The pulverised material, especially if of high density, has a tendency to overrun the fuel charge and to come down to the tuyeres in an imperfectly reduced condition, as well as to form accretions, or scaffolds, on the walls of the upper portion of the blast-furnace, as already explained. The only way to deal with these finely divided ores is to combine them with some suitable material which should give them cohesion and at the same time assist in the operation of smelting without proving detrimental either to the furnace and its working or to the product.

It would not be possible within the limits of the present paper to describe the numerous devices that have been brought forward from time to time for effecting the solidarity of powdered ores. The author will therefore only refer to such methods as are more or less generally known to metallurgists, and to some other processes of a more special character which have been proposed by those having a practical knowledge of the subject at issue. There are three principal methods which have been practically tried for the purpose of bonding small ore before smelting in the blast-furnace. The first of these is agglomeration by heat, the particles being made to cohere by the action of a reverberatory furnace upon the pulverulent mass. The success of this method, however, depends upon the constituents of the ore itself, or, in the absence of those constituents, such as silicates, their addition to the ore. Such methods, however, are found to be costly, a high temperature and a lengthened period of exposure being required to ensure success. A second method is to form the powdered ore into a stiff paste with caustic or slaked lime and water, the lime forming a good binding material. The paste is made into briquettes which are air-dried and become very hard, the lime, as a silicate, tending to facilitate the working of the blast-furnace. The third method is the agglomeration of the powdered ore with carbonaceous material and subsequent coking. Prof. Wiborgh states that this method was adopted by Weissmann, about eleven years since, in the production of so-called ore coke which was made by mixing powdered ore with 20 per cent. of coal-dust and 5 per cent. of pitch. The compound was pressed into blocks and coked at a strong heat applied slowly. This method, however, proved too expensive for practical use, but it was revived later on in a simpler form—namely, by mixing the powdered ore with small coal and coking the mixture in the usual way. Although experimental trials appear to have given good results, the system, so far as the author is aware, has not been adopted in practice owing to the great cost of production on a working scale.

Among other distinguished metallurgists who have devised methods of using finely divided iron ore is Mr. James Riley, a Vice-President of the Iron and Steel Institute, and a Bessemer gold medallist. Mr. Riley proposes to take the slag produced in the manufacture of open-hearth steel, and which already contains some 20 per cent. of iron, and to enrich it up to between 40 and 50 per cent. by the addition of finely divided iron ore. His idea is to mix the powdered ore with the fluid slag as it flows from the furnace or ladle, when casting a charge of open-hearth steel. The slag forms a suitable vehicle for conveying the powdery ores to the furnace in a solid state, and the iron already contained in it is moreover utilised instead of being a waste product. The possibility of making this conglomerate has been proved in practice by Mr. Riley, he having made and used considerable quantities of it. Special arrangements, however, are necessary before the method proposed by Mr. Riley could become part of the daily routine of a steel-melting shop.

Another gentleman who is equally distinguished in metallurgy as a chemist, and who is also a Bessemer gold medallist, namely, Mr. G. J. Snelus, has likewise endeavoured to solve the problem of the utilisation of finely-powdered ores. So far back as 1868 Mr. Snelus patented a process for the direct reduction of powdered-iron ore into the state of metallic iron. A long series of experiments led him to the conclusion, that to obtain metallic iron it is only necessary to expose the finely-divided ore to proper reducing conditions for a very short time. Mr. Snelus considers that the Gerstenhöfer furnace, which is used at Swansea for calcining iron pyrites, will satisfactorily effect the object in view, if heated with a strong reducing atmosphere. The author, however, is not aware that Mr. Snelus has, as yet, carried his proposition into practical effect.

Later on, namely in 1884, another distinguished Bessemer gold medallist, the late Sir William Siemens, endeavoured to utilise the concentrates of poor ores by mixing the powder with tar and forming the mixture into briquettes. These briquettes, in practice, were gradually added to the main charge in Sir William's open-hearth furnace. The results, however, were not satisfactory, and after reasonable trial this attempt to utilise poor ores was abandoned.

Professor Wiborgh, to whom the author has already made reference, has also identified himself with the attempt to utilise poor ores by concentration and direct reduction by designing a furnace for that purpose. This was in 1899, but the author does not think that the invention has been developed into practical use. So far as direct reduction is concerned, the opinion of Sir Lowthian Bell—one of the highest authorities in metallurgical matters—is, that it cannot be economically effected. This has in fact been proved in two instances, one in this country and one in the United States, in which works were started with the object of direct production of malleable iron, but which in time were both dismantled.

We are thus brought back to the starting-point, namely, the mechanical reduction and concentration of the poor ore, the incorporation of the concentrates with a suitable vehicle, and the conversion of the mass into briquettes. In this connection the author will therefore, in the next place, direct attention to the process invented by Mr. Thomas Edison, whose high scientific attainments, as well as his numerous inventions, are well known. Mr. Edison has for some years past devoted considerable attention to the utilisation of poor ores, and his process for accomplishing this has recently been the subject of a considerable amount of public discussion. In this process, as indeed in all others connected with the present question, the ore is first reduced and concentrated, and then made into briquettes. As there are numerous stone-breakers and ore pulverisers, as well as several magnetic separators in the market, all of which are well known, and all of which are, more or less, suited for the purpose of mechanical reduction, the author need not enter upon this phase of the question. Suffice it to say, however, that the author understands that Mr. Edison has invented certain machinery for both these operations. The most important point to the author's mind is the conversion of the concentrates into briquettes, and this will be admitted in view of what has already been stated. And here the author is met by a difficulty in not being able to state the ingredients used by Mr. Edison in the manufacture of his briquettes, which he is informed is a secret. It is, however, stated that there are one or two serious defects in Mr. Edison's briquettes. In the first place they are said to be porous, which alone unfits them, from an ironmaster's point of view, for use in the blast furnace. Another drawback is, that the material used as the conveyor appears to be insufficiently binding to enable the briquette to withstand the burthen in the blast furnace. A third objection is, that the Edison briquettes require to be baked before they are fit for handling, as is publicly stated.

The latest process for the manufacture of ore-briquettes that has come under the author's notice is of British origin. It is that of Mr. Robert F. Strong who, like Edison and others, has for long past given much time and attention to the utilisation of poor iron ores, and particularly to the manufacture of ore-briquettes. Mr. Strong has not devised machinery for the mechanical reduction or for the concentration of the ore, knowing that there is ample and efficient machinery at hand by various makers for this purpose. He confines himself to putting the ore into a suitable condition for use in the blast-furnace. To this end he makes his briquettes of 85 per cent. of concentrate, which he incorporates with 5 per cent. of powdered quicklime, and 10 per cent. of pyroligneous tar = 100 parts. The mass is formed into briquettes under pressure, the briquettes being ready for use directly they leave the press, and do not require to be baked as Edison's do. The tar in the briquette is of assistance in economising fuel in the blast-furnace, whilst the quick-lime forms the best possible binding material and also assists as a flux. Assuming the concentrate to contain 75 per cent. of ore, which it does on the average, the briquettes would contain 63·75 per cent. = 47·81 per cent. of metallic iron. The briquettes would be manufactured at the mines at which the ore is produced, and delivered to ironworks in England at the market price of ore. They would, however, have an advantage over the raw ore owing to the fact that they would be more easily reduced and with a saving of fuel.

Such is the briquette which Mr. Strong has devised for employment in the ordinary blast-furnace using ordinary coke fuel. He has, however, devised another ore-briquette for use in the charcoal furnace in which the ingredients are varied. In the ordinary furnace—except in very small ones—the charcoal will not carry the burthen. With small furnaces the production is necessarily restricted and costly. To meet this and to enable the briquettes to be used in blast furnaces of full size in those countries where charcoal is employed as a fuel, Mr. Strong combines powdered charcoal with the other ingredients, adding also granulated limestone as a flux. By this means charcoal pig iron could be produced in the ordinary blast-furnace at a less cost than common foundry pig, and this charcoal pig would be available for ordinary steel-making purposes with the result of greatly improved products. The pig iron would thus be produced at the mines and no carriage or freight would have to be paid upon the ore. The cost of transport to the steel-works would be that of the metallic product alone, the matrix being left behind in the form of slag.

Mr. Strong proposes to systematise the method of production of the briquettes at the mines so as to render the operation continuous from first to last. By a purely mechanical arrangement the rock ore would be mined, crushed, concentrated, made into briquettes, and delivered direct to the blast-furnaces, whilst the molten metal would be run into pig moulds and delivered thence into railway trucks for shipment. The manufacture of pig iron would thus be a practically continuous process, with a great saving of cost as against the present method of producing pig.

As regards the cost of mining and concentrating the ore ready for the briquette factory, the author gives the following figures, which are those of actual working at a mine in Sweden. At the present time the cost works out at 4*s.* 3*d.* per metric ton of 75 per cent. concentrates. This includes miners' wages, tools, explosives, crushing and concentration, loading and transport to the briquette factory, and management, which comes to 1*s.* 8¼*d.* per ton of raw ore. But it requires 2½ tons of 30 per cent. ore to give one ton of 75 per cent. concentrates. Therefore, 1*s.* 8¼*d.* × 2½ tons = 4*s.* 3*d.* (about), which is the cost of one ton of 75 per cent. concentrates in Sweden, equivalent to 63·75 per cent. per ton of briquettes. These briquettes will yield 47·81 per cent. of metal against 50 per cent. from Spanish ore, but the concentrates can be enriched to yield 63·75 per cent. per ton of briquettes.

Briquettes, to be of any use in the blast-furnace, should be hard, non-porous, impervious to moisture, and capable of standing rough treatment, in the same way as large raw ore. These qualities will enable them to resist the great superincumbent weight in the blast-furnace, and the slow grinding action, which tends to disintegrate them. Above all, they must be able to withstand the gradual increase of temperature in advancing to the melting-point, almost up to which point they should retain their form. This, in the author's opinion, is precisely what the British briquette will do, and what the American briquette will not do.

Before pointing out the working advantages of Strong's ore-briquettes, the author may, perhaps, be permitted to explain for the benefit of those not conversant with blast-furnace practice, that the present method of charging is to put in the proper proportions of ore, coke, and limestone by hand labour, the materials being in their rough state. The briquettes are put into the blast-furnace, and smelted in the usual way, but instead of the quality of the metal produced being largely dependent upon the attendant whose duty it is to feed the furnace, the briquettes when smelted produce, almost automatically, the proper material required, the proper proportions of the ingredients being fixed and invariable in the briquette.

With the present arrangement, especially during night shifts, any neglect on the part of the man in charge of the furnace in not putting in the proper relative proportions of materials, would, and no doubt sometimes does, result in the metal not being uniform in character, or perhaps quite useless for the purpose intended. With briquettes this could not happen, as they would be composed of the exact quantities of the ingredients required to produce a specific result. The weighing of the ore, fuel, etc., in the method now in vogue, and the constant attendance on the blast-furnaces while the smelting is going on, involves considerable expense for labour, a large amount of which would be saved by the adoption of the briquette system. The author believes that the general adoption of the method of making steel from briquettes would result, ıot only in large saving in cost of production, but also in a much ɴore uniform and better quality of the steel produced.

The materials for making the briquettes are to be found in ɡreat abundance in Sweden and Norway, Spain, Canada, New Zealand and Ireland, the latter country having also immense leposits of peat, from which a suitable tarry acid for the ɔriquettes could be obtained.

With the view of ascertaining their adaptability for the blast-furnace, briquettes made on Mr. Strong's system have been tested at the Leeds Steel-Works, at the Normanby Iron-Works, Middlesbrough, and at the Clyde Iron-Works. The briquettes were tested in various kinds of furnaces for temperature, and they were also tested mechanically for carrying the burthen, and both as regards their behaviour at the highest temperatures and their resistance to crushing, they were found, in all cases, to stand equal to raw ore. Samples of these briquettes are exhibited on the table.

Although the present paper deals with the treatment of iron ores, the author may mention that Mr. Strong's system has been adopted at the Broken Hill Mines in Australia, where it has been in successful operation for the past two years with silver ore concentrates. It has also been in use for the last eighteen months at the Rio Tinto Works in South Wales, where it is working upon copper concentrates. The author may add that negotiations are now pending with some leading English steel-making companies for the adoption of Mr. Strong's system in connection with iron mines.

The author cannot conclude without acknowledging the assistance kindly afforded him in the preparation of his paper by your past President, Mr. Perry F. Nursey. Such was the character of that assistance that the author desired to connect Mr. Nursey's name with his own as joint author of the paper. This position, however, Mr. Nursey modestly declined to accept, on the ground that he considered that the services he had rendered were insufficient to entitle him to the honour of joint-authorship.

DISCUSSION.

The President said that he was sure that all would agree with him in according to Mr. Grierson a hearty vote of thanks for his instructive paper. They had heard much of late with regard to the position of the steel industry throughout the world in consequence of what was being done by several large firms in creating huge combinations. They all knew that

English people would have to be on their mettle in order to keep their steel trade in the satisfactory condition that it had been in, and he was sure that they would always be found equal to the occasion. The paper showed that there was one amongst them keenly alive to the urgent necessity of keeping the English steel industry to the front. Mr. Grierson, in opening his paper, referred to a matter which he (the President) had always had closely at heart, viz. the fact that the British people had always been rather behindhand in their appliances, and were not up-to-date with their machines, tools, and methods of working. Perhaps, on the whole, they were rather too much inclined to harp upon that subject, and to discount themselves as a nation; but if the matter were looked into, it would be found that they had the ability to do what was necessary, but Englishmen liked to stick to their old machines and appliances because they were generally so well made that their owners acquired a certain affection for them, and were loth to part with them, and substitute improvements.

Towards the close of his paper the author compared British and American briquettes. He presumed, that in speaking of the American briquette the author referred to the Edison briquette mentioned earlier in the paper. He was glad to see several well-known metallurgical scientists present, and he hoped that they would join in the discussion of the paper, thereby adding greatly to its value.

The vote of thanks was carried unanimously.

Mr. S. Herbert Cox said that he should like to echo the President's thanks to Mr. Grierson for introducing such a very interesting subject. The paper put, in the most concise form, all the details of the matter, and it might appear at the first glance that there was hardly anything to discuss. But still they all looked at matters of this sort from different standpoints as miners and metallurgists. In glancing through the causes which Mr. Grierson mentioned as being the principal ones which allowed the Americans to manufacture iron and steel goods and bring them into this country at a price which would compete with goods of English manufacture, he apparently overlooked one very important item, namely, trade unions. It appeared to him that trade unions had done more than anything else to drive work away from this country. Those organisations attempted to limit competition amongst workmen, and to cut down all labour to one level, so that all men should receive equivalent wages for doing certain work, whether they were good workmen or bad workmen. In many ways, trade unions were, he believed, responsible for a good deal of loss of trade in England. It was true that there were trade unions in America, but they were not in the same category as those which existed in England.

It appeared to him that Mr. Grierson had passed over the question of concentration in a rather light-hearted manner. He referred to it very briefly. He (Mr. Cox) ventured to suggest that the results of concentration had not been as uniformly satisfactory as was assumed by the author. It was true that if they had a magnetic ore associated with earthy impurities only, magnetic separation, or, indeed, water separation, would effect a very fair concentration. But he had yet to learn that a magnetic separator would, for instance, separate titaniferous iron from magnetic iron, and certainly no other concentrator would attempt to do it. Again, there were very large deposits of magnetite which were associated with sulphides, such as copper pyrites, iron pyrites, pyrrhotine, and ores of that sort. He did not understand that the magnetic separation had been up to the present time satisfactory in the discrimination between magnetite and the sulphide ores. It was true that by the Elmore oil concentration process a very good separation was made. He had placed upon the table two samples of a copper pyrites and magnetite which had been separated by that process.

Passing to the question of briquetting, it would appear that Mr. Strong's briquettes were everything that was necessary for furnace work, but was it to be understood that the briquettes, when made with magnetite, contained only 41 per cent. of metallic iron? He read it, in the first instance, to be 63·75, but he since understood from the remarks of the author that they only contained 41 per cent. It was mentioned in the paper that those briquettes were used in a coke furnace, and it was almost unnecessary to mention the fact that of course under these conditions the automatic handling of the ore, on which the author laid some stress, would not apply as the separate charging of the coke and briquettes would be necessary, the same as there would be separate charging of coke and ore. It was true that they might avoid the separate charging of the flux if the briquettes contained sufficient for all purposes. Then, as to the other briquettes, those which were used for charcoal furnaces, he would like to ask Mr. Grierson what percentage of iron there was in them. It seemed to him that it must be very low, if any appreciable quantity of charcoal and limestone was added in addition to the lime and pyroligneous tar used in the other briquettes.

In connection with that point he would also ask whether the briquettes required any further charcoal fuel in the furnace for the purpose of smelting them. Those points all appeared to bear on the value of the briquetting system.

In looking at Mr. Grierson's remarks regarding cost, he found that he stated that the ore could be mined and concentrated and brought to the briquette factory for a sum of 4*s.* 3*d.* per ton. Here again he mentioned 75 per cent. concentration. Did that mean 75 per cent. of iron or 75 per cent. of magnetite in the concentrates? The cost of bringing the concentrates to the briquette works at any rate was 4*s.* 3*d.* a ton ; but Mr. Grierson had not told them what was the cost of briquetting. He (Mr. Cox) would be much obliged if he would give them some idea as to the cost of the installation for the briquetting, and the cost and capacity of the magnetic separators that were used. Those were all points which appeared to bear very closely indeed on the value of the process.

He confessed that he was a little bit hazy about the percentages, but when he looked at the question of 41 per cent. of iron in the briquettes and 30 per cent. of iron in the ore it certainly seemed to him that where water carriage only had to be considered it would probably be much cheaper to bring the ore to England and to erect the works for concentration and briquetting there than briquetting at the mine and sending the briquettes over. He thought that there could be very little doubt that when they had a mineral such as copper pyrites associated with the magnetite that course would be better; but, even with the ores that contained 30 per cent. of iron, if there was only water carriage to be considered would not it be cheaper to bring the ores to England and do the work of crushing, concentrating and briquetting here.

As to the occurrence of these magnetic ores throughout the world, there were several localities mentioned in the paper. He was only acquainted with one of them personally, namely, New Zealand. He saw that one of the briquettes on the table was made from the Taranaki iron sand. He should like to ask Mr. Grierson if that iron sand contained 61 per cent. of iron, what percentage of titanium there was in it? It might be said as a matter of fact that throughout New Zealand from north to south along the west coast there were deposits of iron sand; but those in the north island invariably contained titanium to some extent up to 6 or 7 per cent. Of course ores of that sort would not be suitable for the blast furnace. The iron sands of the south island of New Zealand were nearly all associated with gold to a greater or less extent, and all that gold would necessarily be separated before the briquetting was done. He simply mentioned those points because he thought that probably Mr. Grierson would be able to give some information regarding the deposits in other parts of the world.

Sir HIRAM MAXIM said that he was a consumer of iron, and not a producer; but he thought that if they looked across the Atlantic they might find something that would be instructive in the latter respect. Mr. Carnegie entered the field as an iron producer when there were a great many others already in the field, and he employed larger and better machinery than anyone else. He did more of his work by steam engines and less by hand, and he produced iron and steel on a much larger scale than had ever been done before. The result was that Mr. Carnegie made an immense amount of money, and that notwithstanding that no man had ever paid such high salaries to his workmen. He (the speaker) was told by one of Mr. Carnegie's men that a new apparatus was put in for doing some simple operation, and that the apparatus cost about 500,000 dollars to erect. About the day on which the apparatus was to be started a still better process was brought to Mr. Carnegie. He had the whole thing torn out and replaced by the new system. As they knew, he (Sir Hiram Maxim) was an American. In the States they only saw the best things that were done in England. Americans did not appreciate what England was unless they came over here. If there was anything done in England that was really remarkable, clever, or neat, Americans found it in their illustrated papers; but they did not see the failures. When he (Sir Hiram) came to England and wished to buy tools, he was very much surprised at the antiquated things which English manufacturers called tools. When he told a manufacturer, "I want something better than this," "Oh," said the manufacturer, "this is real English, and everybody knows that English tools are the best in the world." The result was that he had to buy American tools, or imitations of American tools made in Germany. But since those days things had changed very much, and he thought that at the present moment they were doing better in England than they had ever done before. A good many improvements had been made in machines, and there were a good many factories running at the present time with the very best appliances.

As regarded iron ores, there was a great deal of very rich ore in the United States in the form of fine dust. They managed somehow to reduce it. Many of the American ores had the appearance of soft earth or stones which had been broken up, that is, they were similar to ores in which the earthy matter had been removed and the iron left in a finely divided state. Those ores were smelted without making them into briquettes. It was said that Mr. Edison had not been successful in the States with his process. He (Sir Hiram) did not know what particular variety of magnetic ore Mr. Edison used. Some fourteen years ago he (Sir Hiram) invented a machine for working on non-magnetic metals. He did not know that anybody had ever done so before; but he found that about six years later a German brought out a machine in Germany for working the non-magnetic material, and he thought that he had something new; but the German had since found out that his (Sir Hiram's) patents were the first. Whether or not those machines would work on non-magnetic ores he did not know. His apparatus was for the separation of gold and silver and copper, and for taking them out of the sand, instead of taking out magnetic material.

Mr. Frederic S. Warburg said that Mr. Grierson's paper supplied valuable information on a subject which was attracting special attention just now in view of the introduction of Mr. Edison's process for treating poor ores in this country. He was afraid, however, that Mr. Grierson had in one way drawn a somewhat gloomy picture. His paper conjured up a procession of unfortunate ghosts of great men's unsuccessful efforts. Wiborgh, Snelus and Siemens had each been mentioned as having had a shot at the briquetting target, and each in turn seemed to have missed the briquetting bull's-eye. We were told that all the systems they had suggested and which had been put to a practical test, had proved more or less futile, while only those two which were at present more or less unknown and untried in this country, were held out as successes.

Before discussing the briquetting he would ask if it was definitely known what maximum quantity of powdered ore could with advantage be used in the blast-furnace in its natural form. An American ironmaster told him he had at one time worked with up to 75 per cent. of the total blast-furnace ore charge, but that to do that he had considerably altered the shape of his furnace. Several English experts to whom he (the speaker) had mentioned that, were sceptical on the point, and it would be interesting to know if anything definite could be stated about it. He was specially interested in what Mr. Grierson had said about the Edison process, because he had from the first noticed that the question of briquetting had been either glossed over or entirely omitted. He had asked a metallurgical expert what Mr. Edison really used for putting his ore-powder together, and he was told in strict confidence, that so far as he (the expert) was aware, it consisted of but one thing—cheek. He therefore called on the London representative of the Edison process the other day and was informed that certain binding ingredients were mixed with the powdered ore, and that Mr. Edison's first mixture had been incorporated in his patent and published, but, not having seen the specification, he (the speaker) could not throw any light on that point.

Mr. Edison had, however, since that patent was granted, invented a better system which at present was a secret, and that would rather tend to show that his first method was unsatisfactory and required improvement. In an interesting description of his work at Edison in the United States which appeared in the *Iron Age*, it was stated that Mr. Edison's bricks were subjected to a pressure of 20,000 and then 30,000 lb. to the square inch. These bricks did not absorb moisture; on the sample shown to him the other day a little water remained in a pool on the surface of the briquette without sinking in. He was told that the whole process was now being investigated at Edison by a well-known expert on behalf of the English syndicate. It would be exceedingly interesting to hear his report, for at present it would seem impossible to believe that so complicated a process, involving, too, such gigantic machinery, could pay if proper and adequate amortisation was included in the estimated cost of production.

Turning to Mr. Strong's invention, he, the speaker, might explain that having been intimately connected with the iron-ore trade, and having had offers of very large quantities of powdered ore from Sweden, he had been long on the look-out for a satisfactory method of making briquettes. Mr. Strong called on him some years ago and they went very carefully into his system. It was not easy to get out estimates which would enable one to ascertain what his process could or could not do, but it might be of interest to mention that the estimated cost of plant for treating say 1000 tons of ore per diem, worked out roughly at some 12,000*l.*, a figure which of course would be extremely satisfactory.

The whole question, however, hinged on the fact that for his process pyroligneous tar was requisite, coal tar being useless. Mr. Grierson mentioned the composition of the briquettes (and his figures tallied with those Mr. Strong gave him at the time), of 85 per cent. ore, 5 per cent. of lime, and 10 per cent. of wood tar. Now what did that mean? Mr. Strong estimates that to make 10 tons of wood tar, it was necessary to treat no less than 50 tons of wood, and that figure he had found confirmed elsewhere. It was, however, stated that it would be necessary to manufacture the tar in closed retorts, that figure being the maximum obtainable. Of those 50 tons of wood then, 10 would be tar, 15 would be charcoal (which would be available for the charcoal briquettes described), while 25 tons would be waste, unless, indeed, the recovery of other products were made part of the process. In other words then, as 10 tons of wood tar were necessary to make 100 tons of ore-briquettes, it would be necessary to treat 50 tons of wood for every 100 tons of briquettes manufactured. He did not doubt that those figures could be considerably modified in practice, and were pyroligneous tar available in large quantities at a cheap price, the process might be of use. He believed such tar cost between 18*s.* and 30*s.* per barrel, but in any case it would seem that the cost of that process would render it commercially unworkable on any large scale. That opinion was confirmed by a visit paid to one of the works in the North mentioned by Mr. Grierson in his paper, where the process had been carefully tried and subsequently discarded, after a considerable amount of time and money had been spent on it. The company was, and he believed still was, most eager to acquire some good briquetting system, but after the trial just mentioned, recourse was again had to the old and admittedly faulty method of conglomeration with lime and water, which it would seem must still be looked upon as the least of the many briquetting evils.

He might perhaps be allowed to touch on one other matter closely allied to the question under discussion, and which was probably of pre-eminent importance, and that was, could we in England take steps to increase the use of foreign phosphoric ores? Our blast-furnace workers had in the past been sadly spoilt. They had had practically unlimited supplies of 48 to 50 per cent. Bilbao ore of the quality and purity they desired, of the lumpy consistency they desired, and at the price or even under the price they desired, and they had rightly used Rubio ore in preference to anything else that was offered them. It was undoubtedly the best stuff at the lowest price, and at 15*s.* per ton delivered at Middlesbrough, and even less in South Wales, the ore worked out at $3\frac{3}{5}$*d.* per unit metallic iron. Ore briquettes, therefore, to compete successfully must work out on the same basis, or cheaper, unless their other component parts offered distinct advantages over iron ores.

But at a not too distant date, the Bilbao deposits must become exhausted (six million tons for England alone was no small item), and then far vaster fields of phosphoric ore than non-phosphoric ore would be available, especially in Sweden and Spain. On the one hand we saw the Continent—France, Belgium and Germany especially—producing an enormous quantity of basic material, such basic material being moreover actually preferred in Government specifications, whereas over here the basic-making works might be counted on one's fingers.

Although the use of powdered ore and briquettes would undoubtedly play their part in blast-furnace practice of the future, it would appear that it was to the utilisation of phosphoric ore on a large scale, that we must chiefly look for maintaining the position of our iron and steel industries.

Mr. G. J. **Snelus** said that the subject of the paper was one in which he was intensely interested; but before dealing with the paper he should like to join with Mr. Warburg in urging English ironmasters to devote more attention to the use of phosphoric ores. Probably they were aware that he (the speaker) made the first piece of basic steel free from phosphorus, and he was one of the partners in the trio which ran the process up to the time of the expiry of the patents. He had been intensely disappointed that manufacturers in England had paid so little attention to that process. Germany made no less than 6,230,000 tons of basic steel last year, whereas the production of England did not reach a million tons—in fact it was a very long way short of it. There had now been about eighty million tons of basic steel made in the world since he made the first piece, and the production was going on at an enormous increase both in Germany and in America, while English manufacturers seemed to sit down and let the trade drift from them. He was very pleased to hear that other minds were being devoted to the subject, and he thought that Mr. Warburg's remarks deserved serious attention.

Passing to the paper, he would deal first with American competition. He had been in America twice. He was there in the year 1872, and he was there again with the Iron and Steel Institute in 1890. On the last occasion he devoted a great deal of attention in trying to ascertain wherein the Americans beat the English so much in the manufacture of iron, and particularly of pig iron. The American blast furnaces and everything connected with them were far ahead of anything which was working in England at the present time. However the development in England was, he was pleased to say, going ahead very fast, and they had now at Askam a modified form of one of the large American furnaces which Mr. Sahlin expected to turn out something like the quantity which was turned out in the American works. They had also greatly improved blowing engines, which were being erected all over England. For instance, at the Moss Bay works they had an engine which had recently been erected there. It was a three-cylinder engine and would blow up to about 20 lb. pressure. Indeed, he believed that nearly 30 lb. pressure could be got. Great things were anticipated from that engine not only in economy of fuel but in better work. On the east coast several advances were being made with blowing engines, and he hoped that within a reasonable time English blast furnace practice would be following pretty closely on that of America.

With regard to the rolling mills and finishing works, he might mention that a day or two ago he met the manager of one of the largest of such works in America, in company with a late workman of his (the speaker's), who was now a rail inspector, and who did a great deal of inspecting for America. Both these men admitted that England was not so far behind with regard to rolling mills, and that the mills here were as good as those in America. He thought that no one who had seen the modern arrangement of Mr. White at the Barrow Steel Works could dispute that opinion. He believed that that was about the best arrangement of a Bessemer plant and mill that could be seen anywhere. The two gentlemen he had just mentioned said that the only thing in which English manufacturers were behind was the arrangement for cambering the rails so as to save the expense of straightening, and they said that if we adopted the American method of cambering the rails while hot our mills would be equal to anything in the States.

It occurred to him that English manufacturers were beaten by the Americans in consequence of several causes which were quite apart from machinery. In the first place, the managers in America were what were called by Mr. Schwab "hustling men." Managers in England were content to take things more easily. Americans, on the other hand, were always trying to break the record of production. And then their workmen were impressed with the same sort of idea. He noticed when he was at Carnegie's works in America, the workmen were doing work which English blast-furnace men would not do at all. He was struck as long ago as 1872 with the fact that the workmen in America were ambitious to produce the very highest results.

Another point which affected England was that rates for carriage on English railways were so excessively heavy compared with the rates in America. English railways were constructed at a very early period and under conditions totally different from those which ruled in America. Mr. Carnegie could carry a ton of ore for the tenth of a penny per mile, while English manufacturers had to pay a penny farthing or more for the same service. Until something could be done in England to cheapen the freight on raw material, English makers would have a very uphill fight in order to produce cheaply.

He now came to the subject of dealing with fine ore. Mr. Warburg stated that an American had told him that he used up to 75 per cent. of small ore in the blast furnace. He (Mr. Snelus) could not say that he had got so far as that; but he did on one occasion use 25 per cent. of Blue Billy in a blast furnace. He would not say that it turned out economical, but the thing could be done at a lower cost when they had larger ores to mix with it. Blue Billy was a material which was very cheap, but hitherto its finely divided state had kept it from being used in large quantities. But there was now a process for dealing with Blue Billy. Messrs. Morris, of Doncaster, made it into a briquette and burned it in ovens at a high temperature. He saw a sample of that material which he thought was very suitable for blast-furnace work, being exceedingly rich in iron and also pure. He thought that it would be very useful in the Siemens-Martin furnace on account of its great density.

With regard to the use of fine ores, he had been alluded to as having taken out a patent in 1868 for dealing with fine ores. He should like to explain that the reason why that patent had never been worked was, that at a meeting of the Iron and Steel Institute, held at Merthyr shortly after the patent was taken out, he was introduced to Mr. Henderson, of ferro-manganese fame, and, curiously enough, Mr. Henderson informed him that he had taken out a patent some time previously for reducing fine ores, using the same Gerstenhöfer furnace, and had sold his patent to the Tharsis Company, and that Company had allowed it to lapse, so that the patent became public property, and there was no inducement to the individual to work it. That was the reason that his (Mr. Snelus's) process was carried no further. He still believed in it. Mr. Menelaus, who was then the general manager of the Dowlais works, believed in it. Mr. Menelaus had had an interview with the late Dr. Percy, whom he asked whether the process was likely to be successful. Dr. Percy said that theoretically it was all right: it simply required to be tried in practice. He still believed that there was a possibility of reducing fine ores by some system of the sort. He did not say that the Gerstenhöfer furnace was the best, but he thought some process could be used. The finely divided ores lent themselves very perfectly to reduction because of their fine state of division. He found that if the fine iron ore was kept in a proper reducing atmosphere at a temperature of 700 or 800 degrees it was reduced in less than two minutes. He was chemist at the Dowlais works at the time he had been speaking of. Mr. Blair, who afterwards brought out the Blair process, was working on the Ellershausen process, and he (Mr. Snelus) showed him the process for getting metallic iron from oxide of iron in two minutes under proper conditions. The removal of the oxygen from the oxide of iron was not a question of long duration if they had the proper conditions.

He would now pass to what he considered to be the principal part of the paper. It appeared to him that it was like the play of "Hamlet" with "Hamlet" left out. He had hoped to hear what the Edison process was for separating the iron ores other than magnetic. They all knew that it had been stated in the papers that Edison had invented a process whereby he could purify the iron ores of Dunderland, although they were not magnetic. He (Mr. Snelus) paid a visit to the Dunderland property two or three years ago. He was struck with the extent of it. It was stated that it ran into eight hundred millions of tons. The deposits could be traced over a length of twelve or fifteen miles, and in some places it was said to be uncovered across the veins up to 500 feet. He found one outcrop of over 100 feet. From that it might be imagined what an enormous deposit of ore there was there. But, unfortunately, that ore was of a very peculiar nature. It was specular ore in the shape of very fine scales, interfoliated with a large quantity of sand. From the examination of the portion that he particularly looked at he found that the ore in the deposit would average 45 per cent. of iron with nearly 30 per cent. of earthy matter. If that earthy matter could be removed by a simple process, such as they were told Edison's was, it would be a matter of immense importance to this country, because the deposit was so near England that about three days would suffice for bringing the ore here.

The deposit extended, as he had said, for a length of twelve or fifteen miles, and was parallel or nearly parallel with the Dunderland river, and could be brought down to the little port of Mo at a very small expense. In fact an electric railway could bring it down, and the railway could be run with the water-power of the district without any difficulty. The ore could be raised by quarrying at an estimated cost of 1*s.* 9*d.* per ton. If it was put at 2*s.* 6*d.* per ton the cost would still be very low. On account of the earthy matter, it required, of course, two tons of ore to make one ton of useful material; but if a method could be got, such as Edison was said to have got, for treating the ore, the ore would be the cheapest that, as far as he knew, had yet been got in any part of the world, and the quantity was undoubtedly enormous. He reckoned that if the ore could be so treated it could be delivered in Middlesbrough, with 56 per cent. of iron, at about 8*s.* 5*d.* If any process could be got for concentrating it, that process would probably remove a great deal of the phosphate which existed in the ore. The best portion of the ore ran up as high as 65 per cent. of iron and only about 5 or 6 per cent. of earthy matter. The poorer portions went down to 33 per cent. of iron and 33 per cent. of earthy matter.

It could be sorted by hand. He found a large number of piles of ore which had been hand-sorted, the average of which contained nearly 60 per cent. of iron. Hand-sorting, of course, could not compare with mechanical appliances if they could be got. But how Edison was going to deal with the specular ore he could not understand. They must first convert the hematite ore into magnetic ore before they could use a magnetic concentrator. But, given the concentrate, he did not think there could be any very great difficulty in making it into briquettes, if briquettes were needed. He thought that the first thing was to take the sandy portion out of this enormous deposit, and then there would be something which would be of very great advantage to this country because of its nearness and the cheapness with which the ore could be brought over.

Sir HIRAM MAXIM said that perhaps he might throw a little light on Edison's machine. According to the papers it had been stated by Mr. Edison that some of the ore which he operated upon was not affected in the least by approaching it with one magnet, but if the action of one magnet was followed by other magnets in rapid succession, say fourteen magnets or more, the material was affected and could be moved. He (Sir Hiram) need not tell them that the same thing was true of other metals as well as of iron. No one could move copper or silver by approaching it with a magnet, but if magnets with opposite polarities passed it in quick succession, copper, silver, gold, or other similar metals could be moved. Magnets attracted a piece of iron simply because it was iron, but a material which was non-magnetic could only be moved by being temporarily made into a magnet. When a rapidly alternating current was generated in a piece of metal, that metal would have a tendency to follow the magnet. In other words, the metal would a great deal rather pass off in the direction of the magnet than be heated by electrical disturbance. An instance might be given to show how very fine the magnetic action was. If they took a beam of light and passed it through a polariser, and then passed it between the poles of a magnet, the magnet not being excited at the time, and then turned the analyser round so that it just barely shut off the light from the screen, and then excited the magnet, the magnetism would itself twist the light sufficiently to cause some of it to get through the analyser, and so show on the screen. If magnetism could work with anything so impalpable as light, it would evidently work with other things. If a piece of copper was put into the apparatus which he (Sir Hiram) had made, and not allowed to move by the influence of magnetic induction, the copper would be heated, but if it was dropped in and allowed to fly out, it was not heated. When not allowed to move with the magnets it was heated quicker than it could be with a blow-pipe. He had thought it probable that Edison's machine worked in that way. Probably there was a series of magnets in which one rapidly followed another.

He (Sir Hiram) had tried his apparatus on many things, and it had been tried in Germany. The patents had expired, but it was a thing to experiment with, and he thought that a great deal might come of it if the matter was properly gone into. They might consider it as a magnetic brush. Suppose they had a very powerful magnet with the pole extensions approaching each other; if they passed a piece of copper between the poles it would be retarded, and would feel like cutting through a piece of cheese. Suppose they had a lot of those magnets rotating, and that non-magnetic material was placed in the path of the poles, it would be brushed along with the poles. The magnets would have more effect on some things than on others. For instance, they had more effect on copper and silver than on anything else, and, of course, very much less effect on low-grade ores.

Mr. A. STANLEY ELMORE said that he had come to the meeting to be educated on the question of briquetting, but the discussion appeared to him to have gone to a very great extent away from the subject of the paper. His interest in the paper and discussion arose principally from the fact that he was at present working on the Elmore oil concentrating process in the treatment of magnetite ores which contained copper pyrites, and in some cases pyrrhotine as well. Those ores had not been successfully treated so far by magnetic separation. Magnetic separators did not on that class of ore appear to give a clean magnetite, because they evidently, to some extent, mechanically entrapped particles of the copper pyrites. But even if they did not entrap particles of copper pyrites, the modern magnetic concentrator worked with such a strong magnetic field as to attract particles of copper pyrites.

Those ores had so small an amount of copper in them, and it was associated with so much iron, that they were useless to the copper smelter. On the other hand, the presence of the sulphur and copper rendered them unfit for the iron smelter, and as it had been found quite impossible to separate the copper and iron, either by magnetic or water concentration, those ores had, up to the invention of the Elmore process, been quite valueless. That process had been found particularly adapted to separating those; that was, by getting a very clean copper concentrate, and at the same time leaving a very clean magnetite as tailings. If the magnetite was associated with objectionable quantities of silica, dolomite, and so on, it would require some further process of separation, but in some of the deposits, at any rate in Norway and Sweden, the magnetite was clean in the sense of its being practically free from silica and other deleterious substances, except copper pyrites. Therefore if by the Elmore process they extracted the copper pyrites, they got a clean product of practically pure magnetite as tailings, thus making both the copper and iron in the ore of value.

It seemed to him from what had been said that evening that many people, as Mr. Warburg had said, "appeared to have been shooting at the briquetting bull's-eye without hitting it." The meeting had not been favoured with any figures as to the actual cost of briquetting. It seemed to him that success in the treatment of iron ores by any process which necessitated the grinding of the ore, depended to a very great extent upon the cheap and effective briquetting of the product. He believed that Mr. Sulman, who was present, could probably give some definite figures about the cost of briquetting, and as that gentleman had made comparative tests of the Elmore process and the magnetic process in the treatment of the particular copper magnetite ores referred to, he might also give some figures on that head.

Mr. H. L. SULMAN said that the paper had been exceedingly interesting and had covered a wide area. But they were all asking for more details. For example: the round figure which the author had given for mining and milling costs, including dynamite, miners' wages, tools, transport, power and crushing, namely, 1*s.* 8¼*d.* per ton of raw ore, seemed to be impossibly low, and he should much like to know the items composing this total. It amounted to only one-third of the lowest mining and milling costs hitherto recorded on similar work. Moreover the author had failed to give detailed costs of the Strong process.

Several of the speakers who had preceded him had referred to what he might term "the Edison bogey," which had lately been raised by the press in such a startling manner. He thought there was little of sterling originality in the published accounts of Edison's process. As a matter of fact there were many magnetic processes known to be doing excellent work at the present time, dependent upon the use of a magnetic field of greater or less intensity and capable of alteration; and the results obtained by several of those magnetic concentration methods were very remarkable. The Wetherill process seemed to be able to discriminate (1) between copper pyrites and pyrrhotins, and again (2) between pyrrhotine and ordinary iron pyrites, and so on. The Metternich and Sonnenstein processes were also largely used in New South Wales for concentration of Broken Hill ores. There those processes were successful, effecting a considerable separation of galena from the zinc-bearing mineral. The zinc blende being associated with iron, it was found that by subjecting the finely crushed ore to the magnetic field, the blende portions were deflected and separated from the more leady portion of the ore. He believed that the Metternich process had been carried to such an intensity of field that it had been made to discriminate between calcite and dolomite where one of those products contained traces of iron. It was not therefore beyond the range of common knowledge at the present time that a magnetic field could be made to separate specular iron or hematite from magnetite. Therefore he did not think that they needed to be very seriously exercised by the Edison process so largely advertised by the sensational daily papers. As far as they could gather from those sources there was the usual proportion of inflated statement and mystery which had already characterised several of the inventions announced from Menlo Park, but which, nevertheless, had not hitherto altered the earth's axis of rotation.

With reference to the gigantic ore-crushing schemes put forward as integral portions of the Edison method, practical men had already fully explored that ground. It was no speculative problem in the realm of the higher electrics or in wireless telegraphy, but definite mechanical experience; and as to high-speed, heavy-weight, crushing gear devices, the experience of years in all parts of the world had been that such developments were useless and led to a blind alley. He thought that they would all agree with the statement of the author in which he expressed the opinion that the present economical status of ore-crushing and reduction machinery was fully equal to any demands likely to be made by any metallurgical process from whatever quarter it might hail. He instanced the enormous daily outputs from the crushing installations by rotary plant at Broken Hill, Mount Morgan, etc., and by stamps in the Rand or in California.

But as there were brave men before Agamemnon, so there were experimentalists who reduced magnetically separated iron ore by briquetting methods before Mr. Strong and before Mr. Edison. There was the Swedish Landin process, which had been worked successfully, he believed, for many months past. The ore was crushed, separated, and the briquetting effected by the admixture of a small portion of tar and lime. The briquettes were non-porous and hard, and could be used in an ordinary blast-furnace. But at this point the Landin process diverged from Mr. Strong's method, approaching that of Edison inasmuch as the briquettes were submitted to the action of a reducing atmosphere at a temperature of about 700 or 800 degrees Centigrade, with the result that there was a very rapid reduction of the iron in the briquettes to the metallic state. The briquettes came out of the reduction oven red-hot, and were at once smelted to metal in an open-hearth furnace. The red-hot briquettes were as hard as stone owing to the skeleton of metallic iron which they contained. That was, therefore, a third process dependent upon briquetting, and it seemed to him to be one worthy of very serious consideration.

As regarded the Elmore oil method, he might say at once that his only interest in it was from the fact that he had lately been very carefully investigating its application to a large number of mines: two of those cases had been mines in which the magnetite was associated with various metallic sulphides and largely with copper. Magnetic concentration had been tried and had failed either to withdraw sufficient copper to make it successful as a copper concentration process, or to leave the magnetite sufficiently clean from sulphur and copper to render the magnetite suitable for the production of steel. As the result of many trials he had found the Elmore process effect such a separation very perfectly, and to yield pure magnetite suitable for briquetting: he had, therefore, advised the adoption of the oil method in place of magnetic separation. The Elmore process simply consisted in bringing the crushed ore pulps (in water) into intimate and continuous contact with heavy mineral oil. The oil had the property of sticking to the sulphide minerals, whilst it let the oxidised minerals and the gangue pass entirely away. That was a very remarkable property, and a satisfactory explanation of it had yet to be sought, but the results were very complete and very perfect.

Mr. J. Bridges Lee said that the magnetic method of concentration was a subject of very great interest, and he thought that some of the remarks of Sir Hiram Maxim, giving his theoretical explanation of the way in which a powerful electromagnet could act upon bodies which were not themselves magnetic, were most interesting. They all knew, of course, that powerful magnets would attract certain substances such as iron, nickel and cobalt, and a very few other substances in a minor degree, even from a position of rest, because those substances were magnetic. But when in a state of motion a number of other bodies would also be affected by the magnet. Any conductor which they might attempt to move through a magnetic field was immediately affected, and was always affected in the same sort of way, namely, that it always met with increased resistance to its motion across the magnetic field. It was obviously conceivable as a matter of scientific theory that it might be possible to separate from rapidly moving mixtures of particles, bodies which were conductors from bodies which, passing through a magnetic field were non-conductors, even though none of those bodies might be magnetic. He was not aware whether hematite was itself a conductor; perhaps it was so in a minor degree.

There was another fact also in connection with magnetic separation, which was worthy of consideration; and that was that, besides magnetic bodies, there were in nature a large number of bodies which were diamagnetic; that was to say, they were the reverse of magnetic. The tendency of those was to be repelled by the magnet. The repulsive force of the most powerful magnets acting on those bodies must always be very feeble, but still it might be sufficient to account for perceptible differences of behaviour in the case of different ores.

Mr. PERRY F. NURSEY said that although the discussion covered a very wide area, the point of the paper lay within a very narrow compass. The whole question was simply that good iron ores were gradually giving out both in quantity and quality, alike at home and abroad. The necessity therefore arose for using ores of a weaker and poorer quality, but which nevertheless were available and suitable for the purpose required. The question was how best to utilise them, and that was no new question. It had been before the metallurgical world for some years. In 1895 he was himself engaged in an investigation of the subject. He was associated with an endeavour to utilise a large magnetic iron sand deposit on the north shore of the Gulf of St. Lawrence, 500 miles below Quebec. The deposit was about seventeen miles long and a mile and a half wide. It was discovered about thirty years ago, and was sold in lots by the Government to various influential persons who bought it up with great avidity. At the time he was engaged in the matter there was a process known as the Porter process for extracting the metallic iron from the sand, and which, it was stated, would reject the silica and nearly the whole of the titaniferous iron. The matter proceeded to a certain point, but it was found that, given the deposit and the means of extracting the iron sand, there was no means of putting it into an efficient condition for the blast-furnace. Briquetting had been tried and had not then succeeded. That was the whole gist and point of the paper. There was ample machinery at hand for crushing and concentrating low-grade ores, but they had not so far reached the point at which they could place the low-grade ores in a satisfactory condition in the blast-furnace. Here Mr. Strong stepped in, and if Mr. Strong succeeded in producing an efficient briquette he would be doing a very great service to the iron and steel industries of the country.

Mr. R. F. STRONG said that Mr. Cox suggested that low-grade ores might be brought from Sweden and Norway in the raw state and treated at the iron-works here. To that there were various objections, one being, that the low-grade rock ore contained large quantities of silica and other objectionable matter, and they would be paying transport on that waste. Now, in Sweden and Norway there was abundance of cheap wood suitable for making the tar acid necessary for briquettes; so that close to the mines there was every requisite for carrying out that process.

The question of cost had been raised by Mr. Sulman, and he (the speaker) understood that Mr. Grierson had not included it in his paper, being under the impression that the commercial aspect of the subject should not be gone into. But he (the speaker) would be pleased to give the meeting some figures in that respect. In Sweden the actual cost of mining the ore, and of transport to the concentrating plant, was 8¼*d.* per metric ton, and the concentrating and the delivering to the briquette bins was 9*d.* The factory wages of briquetting and delivering to railway trucks was, according to the factory output per day, about 6*d.* to 9*d.* per ton, or, say, with boiler, fuel, stores, etc., 1*s.* per ton. Mr. Sulman had said that it would probably be 4*d.* to 6*d.* He (the speaker) thought so also from his knowledge of various briquette factories.

They had been told that Mr. Edison had invented some wonderful crushing rolls, and that they were 8 feet long by 6 feet diameter, and weighed 375 tons. He might say, in passing, that Krupp made concentrating plant. His rolls were 6 feet by 3 feet, weighed 12 tons, and gave good results in practice. All those crushing rolls were on the principle of the old Cornish ore crushers.

With regard to briquette plant, the cost also varied with the output. A plant to briquette 1000 tons per day would cost about 8000*l.*, all told, but without the wood-distilling plant. That was made something like a modern coke-making plant, and cost about the same.

Another point raised was the cost of tar. In his figures he took it at the selling price here, but in Sweden and Norway the cost would be much lower. So he thought that Mr. Cox would see that it was advisable to make the briquettes in Sweden and Norway, and ship them as ore to this country, where, using coke and the necessary additional limestone, and taking wages, furnace charges, etc., at the same as working on Spanish Rubio ore, the hematite pig-iron from the briquettes would cost 51*s.* per ton; but there would also be a saving in the labour item and increased output, which was not taken into account. However, what he would like to strongly bring forward was that, with these same briquettes, having the charcoal added and smelted in Sweden and Norway, charcoal pig-iron could be delivered in England at 41*s.* per ton. And, at that, even the low-grade ores in Ireland and Cornwall could be made into pig. In those places there was abundance of peat, and from that the necessary charcoal and tar acid could be made.

From recent experiments he had made with Irish peat, he could say that the tarry acid was even better than that from wood; so that districts having peat and ore could, in the future, be entirely independent of coal in the production of iron, and could produce it at even a much lower cost than under present conditions. Mr. Snelus and many of the other speakers agreed that it was in the low cost of producing pig-iron in the United States that we were beaten, this enabling the American makers to send out finished steel at a lower price than English makers could produce it here. He knew that, in the large works in the United States, the cost of hematite pig-iron was 35*s.* per ton; so that English makers could, by smelting Swedish and Norwegian ores, and importing the pig at a cost of 41*s.*, hold their own and defy the competition of the United States.

The question was raised of titanium in Swedish ores, and New Zealand iron sand, and also as to the percentage in each. In the Swedish ores a great portion contained about 5 or 6 per cent.; but in the concentrates it was about 2 per cent. In the New Zealand sand there was 8 per cent. No doubt titanic rock ore was difficult to smelt alone. In the United States they mixed an equal quantity of hematite ore with it; but titanic ore concentrated and briquetted was smelted quite easily. Practically, each grain of ore was covered by the lime and pyro-tar which enabled it to reduce easier than hematite raw ore. As to the effect of titanium, he thought that Mr. Snelus would confirm his opinion—he having a few years ago investigated this subject—that, even with 8 per cent. of titanium in the ore, there was only 1 per cent. present in the pig; and at the present time nothing definite was known as to the effect of titanium on steel; but all, including Mr. Siemens, were of opinion that it greatly improved its quality and considerably toughened it.

Mr. WARBURG said that he had not understood what the actual cost of the wood tar came out at. He had understood that it came out at from 18*s.* to 28*s.*, and he had heard a mention of something about 4*s.* Was that the cost of the wood tar? What did Mr. Strong reckon the cost of the wood tar at? If the charcoal cost 20*s.* a ton the wood tar from that charcoal would cost nothing. In addition to the tar there would be a little by-product. He had taken the tar at 20*s.* a ton, the same price at which he bought tar in this country. He was speaking of the tar from the charcoal retorts.

Mr. GRIERSON, in replying upon the discussion, said that he might speak of the paper as a somewhat superficial one; but he ought also to say that it would have been a great deal fuller if it had not been that the rules of the Society, like those of other societies, precluded him from going largely into anything like advertisement. When Mr. Warburg said that he presumed that Mr. Strong's was the only system of hitting the bull's-eye, he was quite right. He (Mr. Grierson) believed that it was the only system, and that it was a great deal better than any other system that had ever been brought before the public up to the present time.

Mr. Cox had asked a great many pertinent questions; but he believed they had been answered with the exception of one. That one was a really very important one, and was related to the commercial side of the subject. He believed that by making the briquettes in Sweden and bringing them to England a charcoal iron could be produced a great deal more cheaply than it was produced now. No alteration of the blast-furnace would be required. That to his mind was a strong point. The idea of bringing ore from Sweden and making it into briquettes in this country and then carrying on a process of that sort had already been answered by Mr. Snelus. That gentleman had told them that the railway charges would simply crush the business as they crushed a great number of other things. He believed that Mr. Snelus was quite right in that statement. As to Edison's process, some of the speakers had stated that they came for the purpose of hearing and understanding a description of it; but he had thought that it would be unnecessary to enter fully into that matter for the simple reason that on the 30th March (if he remembered the date rightly) there was a detailed description of Edison's process in the London 'Daily Express.' The article went into such detail that he thought nothing further could be required. What Sir Hiram Maxim had said was fully in accord with the statements made in that paper and he (Mr. Grierson) remembered that it was distinctly stated there that the briquettes should be porous. They all knew that it was very good that ore which was put into a blast-furnace should be porous because they wanted it to break up. But in the case of briquettes, if they were porous they would break up before they ought to do so. He would thank the members for their reception of his paper and would express his gratification at the practical nature of the discussion that had taken place upon it.

June 3rd, 1901.

CHARLES MASON, PRESIDENT, IN THE CHAIR.

CONCRETE SUBWAYS FOR UNDERGROUND PIPES.*

BY A. TAYLOR ALLEN.

INTRODUCTION.

THE author believes the first subway for underground pipes constructed in England was one in the City of London about the year 1860, during the time the Holborn Valley and other improvements were being carried out. This was followed a year or two later by one in the City of Nottingham, the place, outside the Metropolis, which has proved a pioneer in the construction of subways. Since then the author has looked in vain for an extension of these new arterial thoroughfares, for beyond one constructed at St. Helens in 1899 there is an almost entire absence of subways being made for minimising the evils resulting from the continuous breaking up of our roads and streets.

The pages of professional journals and the literary efforts of technical writers have been very meagre indeed on this large and important subject. The volumes of the Society's Transactions appear to be equally barren of information upon the subject. The only paper they contain is that read in 1895 by our present President, Mr. Charles Mason, who dealt with the question in a practical manner. He pointed out the necessity for the introduction of subways in large towns, clearly stating the requirements of the case and submitting a design, prepared by himself, for a subway, in which he proposed to meet those requirements.

That there is growing public interest in the condition of our roads and streets cannot be denied, and the extensive work involved in their upkeep increases every year. The fact that when a pipe in a busy and important thoroughfare has to be taken up, or a new connection made, the only thing that can be done is to break open the road is certainly somewhat of a blot on our boasted twentieth century civilisation.

The author therefore considers this an opportune moment to discuss the relative merits and demerits of subways for underground pipes, as at the present time our carriageways are paved over a number of gas pipes that may soon be of insufficient capacity, over water mains that were laid years back when the requirement was not nearly what it is to-day, and over sewers that were constructed to meet the requirements of the past century.

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* A Society's Premium was awarded to the author for this paper.

It is only to be expected that the tearing up of our roads and streets for the purpose of localising some leakage, or of reinstating a defective pipe, will be always with us, unless some underground passage is constructed to receive the various pipes. Where such subways as those referred to in this paper are constructed in the metropolis there has been no occasion to break through the surface of the streets for the purpose of necessary attention to the underground pipes, while in Victoria Street, Nottingham (one of the central streets), the carriageway was not broken open for twenty-five years, and, consequently, during that period, not one single penny was spent on such repairs in that particular street. The secret of this is that a subway contains the gas, water and other pipes, with their connections. The desirability of a subway for such pipes in all new leading thoroughfares was recognised at a conference of the London County Council and representatives of the city corporation, vestries and district boards held last year.

Breaking up Streets.

The opening of roads for the laying of new mains, repairs to existing ones, or other public services is a continual cause of complaint, and one of the stock grievances of the public; and rightly, too, for during the seven years the author resided in one of the now municipal boroughs it was a daily occurrence to see a street cut open, necessitating inconvenience and hindrance to vehicular traffic, and also pecuniary loss and delays to men of business and to tradespeople through traffic and business being greatly impeded.

The necessary total or partial blocking up of a street interferes with, and in some cases suspends, the traffic while the works are in progress, and means the serious diminution of business. Trade is carried on at a great disadvantage, entailing extra expense and labour, first in getting goods to the shop, and then in delivering to customers; and there can be no doubt that the breaking up of the roads operates temporarily to the prejudice of many business houses. In the case of Martin *v.* London County Council (Queen's Bench Division), before Mr. Justice Kennedy, on July 30th, 31st, and August 6th, 1898, it was decided that the owners of such premises have no claim for any loss sustained.

As a criterion of the traffic passing along certain roads, the following abbreviated return at once reveals the inconvenience caused during the occasional or prolonged interference with the carriageway for the laying or repair of pipes.

Vehicles passing along—

Westminster Bridge Road, London, in 12 hours	6588
The Wicker, Sheffield, in 8 hours	6315
Station Road, Portslade-by-Sea, in 8 hours	1877
Wellington Street, Strand, in 12 hours	9816

The latter was taken for the purpose of parliamentary inquiry.

The surface of the road is continually undergoing a surgical operation, and in support of this statement the author gives extracts from some "Annual Municipal Engineering Records."

In the Hammersmith district the road was broken open in 1904 places, an area representing 6238 superficial yards was disturbed thus, and subsequently made good by the vestry's men, the expense chargeable being 796*l.*

In the Poplar district the road was broken open in 1187 places for the access to the gas pipes, the expenses chargeable being 551*l.*

In Sheffield, 5605 vouchers notifying the breaking up of the road for various purposes have been received; Eastbourne, 988; Portslade-by-Sea, 642; Teddington, 348.

The result of cutting trenches longitudinally and transversely through the road is detrimental to the road, and the contour is disfigured for some length of time, and in many cases it is very difficult to replace the surface in a satisfactory manner, in addition to the expense incurred and the considerable time that must elapse before the effect of such disturbances becomes imperceptible. Next to indiscriminate stripping and mixing of the surface material and foundation of a road, there is nothing more pernicious than the slack refilling of the trenches by gas, water and other companies, which produces subsidences of a serious nature, the wearing life of the road being irregular and greatly reduced.

STATUTORY POWERS.

It is never to the public convenience that two or more companies should have power to interfere with the streets. There is so much regarding the breaking up of public roads scattered throughout the various acts, that the author considers it will be found sufficient to have the substance of the sections collected into a short compress and in direct sequence.

The Gas-Works Clauses Act, 1847, empowers the undertakers to open and break up any road and lay down and place pipes, conduits, service pipes and other works, and from time to time repair, alter, or remove the same, subject to three clear days' notice being given to the clerk, surveyor, or other officer of the Local Authority, before beginning such work.

The Water-Works Clauses Act, 1847 (incorporated with the Public Health Act, 1875, Sec. 57) provides similar power, and Sec. 52 gives power to a private individual to open or break up so much of the pavement of any street as shall be between the water main and his house, building, or premises after giving due notice. It has been decided by the courts that the word pavement as used in this section, is not confined to the footpath only. Provisos are also contained in the Tramways Act, 1870; the Railway Clauses Consolidation Act, 1847; the Electric Lighting Act, 1882; Forrest Fulton's Act (the commonly known title of the Water Companies Regulation of Powers Act, 1887); and the Telegraph Acts, 1863, 1873, 1878, 1892.

Underground Pipes.

Many of the main streets of our large cities and towns are already undermined with a complete network of pipes of various descriptions and sizes, spread over the whole area of the road, presenting what may well be compared to a living organism which is daily growing in complexity. The author has prepared a typical section of a street in his comparatively small district (Fig. 1), showing the pipes which exist under the surface. If it were possible to present a typical section of some of the crowded thoroughfares in our large cities and towns, showing what lies beneath the surface, we should simply be amazed.

The pipes usually to be found in part or whole under the surface of all our streets, are as follows: Foul sewer, storm-water sewer, house drains and connections, gas mains, gas services, water mains, water services, telegraph wires and cables, telephone wires, electric light and power conduits, distributing electricity mains and services, pipes for conveying hydraulic pressure or compressed air.

When a new site opposite the Bank of England was granted to the Central London Railway Company for their terminus, the author believes it was on the understanding that the company should construct a public subway which, besides serving as an entrance and exit to the station, would connect all the thoroughfares in the locality. The work of this new subway presented many great difficulties, not the least of which was that dealing with the great underground mains, there being a 30-inch gas main, a 24-inch gas main, two 24-inch water mains, and a main containing heavy hydraulic pressure, and below these was a brick sewer, 8 feet wide by 7 feet high. At Hampton there are altogether some fourteen miles of large trunk mains of various water companies, varying in diameter from 30-inch to 42-inch, laid at varying depths, and in anything but regular or straight lines. In some streets there are as many as six of these huge pipes, running side by side, as well as small gas, water and other pipes.

At Fig. 2 the author gives a section of a typical subway, designed by him for Urban districts.

Danger from Present Complication.

There is nothing of greater importance or more essential to the health and prosperity of the community than pure water, and in order to ensure the health and safety of the people, works of great magnitude have been undertaken by public bodies and private companies (in face of opposition) to surmount every difficulty in providing a pure supply. Yet after this has been accomplished, paradoxical as it may seem, the pipe conveying the supply is allowed to be hidden, and, with a proportion of important fittings, it lies beyond the proper inspection and supervision it is necessary they should have. Moreover, owing to the existing complication of underground pipes, it is impossible even to casually inspect the water mains, and, being for the most part hidden from sight, a defective joint, or a burst, may remain undiscovered for a length of time. The author remembers witnessing a road being opened for the purpose of localising a leak in the water main, when it showed that the gas company had utilised the water main as a saddle bracket for resting their pipes on in crossing the road. In another case, the first intimation of a leakage in the water main was reported to him by the sewermen.

As is well known, iron pipes have a tendency to rust and decay when embedded in the earth, and are liable to burst, and in case of their being in close proximity to a leaky drain or sewer the result might be serious. The necessity for more rigid supervision over gas and water mains and service, is clearly shown in the present day of speculative building. At Penzance, only last year, the engineer reported two bursts of a serious nature in the 9-inch supply main from the reservoir to the town, the second of which caused considerable difficulty, there being a second main crossing over the burst pipe.

Allusion must be made to the danger arising from the use of a steam roller in consolidating a macadam road. The actual cost of repairing a damaged main is of very little consequence compared with the incidental compensation which may arise from a consequent explosion of gas and loss of life. Serious results, causing loss of life and danger to property, involving heavy compensation, may happen any day under the present system of laying underground pipes. A case occurred only a few weeks ago at Stratford-on-Avon, the author's native town. A gas main was broken by the corporation roller, and the escaping gas found access into the sewer. An explosion occurred at a considerable distance off, when a match was struck by a man in his outhouse. In Driscoll *v.* Poplar Board of Works, the local authority were held liable in damages for personal injury sustained by the plaintiff, owing to the explosion of gas which had escaped into some house drains from a gas main broken by a steam roller belonging to the board.

Development of Underground Pipes.

Owing to modern requirements there is a large increase in the number and size of all pipes, and, owing to the Mersey and Irwell Act, 1892, the Thames Conservancy Act, 1894, and the Rivers Pollution Acts, 1876 and 1893, being more rigidly enforced, and in view of the possibility of the next act making it still more compulsory for all sewage to be treated before passing the effluent into the river, some authorities may be obliged to make separate sewers, which will probably add to the already numerous pipes now existing another distinct set of pipes to carry off the storm water. And it must not be forgotten that the Local Government Act, 1888, imposes the duty on County Councils of enforcing the provisions of the Rivers Pollution Acts.

The use of water grows incessantly, and even more rapidly than the population, and the constant water service to a large and increasing population for domestic and manufacturing purposes necessitates the putting in of larger or duplicate mains. During recent years the rapidly increasing demand for electric current makes frequent additions to the wires necessary, and provision has to be made for these, together with the increasing number of telegraph wires. Moreover, the newer system is to lay the telephone wires underground. Of recent years many roads have been opened for the purpose of laying electric mains, these usually being laid in brick or concrete conduits, or Callendar bitumen tubes or iron pipes, and the author is aware of cases where it has been a matter of extreme difficulty to find space for these mains.

PARTICULARS OF EXISTING SUBWAYS.

The author has obtained the following particulars of existing subways, which may be of interest in connection with this paper.

London.—The size of the subways laid in Queen Victoria Street, Victoria Embankment, Northumberland Avenue, Southwark Street, Shaftesbury Avenue, Charing Cross, and Rosebery Avenue, varies from 14 feet by 7 feet 6 inches to 8 feet by 7 feet, the construction being of brick in cement, with semicircular arch and necessary side entrances. In the case of Northumberland Avenue, a lateral way leading from the subway to the footpath is constructed for every two buildings. The various mains arranged in the subways are generally gas, water, electric light, hydraulic supply, telephone and telegraph cables. The average cost complete is 15*l.* per lineal yard.

Nottingham.—One subway is 10 feet wide by 8 feet 6 inches high, constructed with a semicircular arch. Under the causeways on each side of the streets vaults are constructed 8 feet 6 inches wide by 9 feet 3 inches long, and about 7 feet high. These vaults are rented by the purchasers of the building lots adjoining, at 1*l.* each per annum, being 5 per cent. on the outlay. The sideways, which form the means of communication between these vaults and the subway, are placed ordinarily about 40 feet centre to centre, and are 4 feet high by 3 feet wide. In one of the principal subways the following pipes and cables are accommodated: One 15-inch sewer; two gas mains about 8 inches diameter; two water mains about 4 inches diameter; telephone cables; telegraph cables; and twenty electric cables. The cost of the subway proper, and including everything appertaining to the subway itself except the sewer, was about 10*l.* per lineal yard. The vaults under causeway cost about 20*l.* each.

St. Helens.—This subway is constructed wholly of concrete with the exception of a 4½-inch ring of blue brick to form the arch around which the concrete is laid. It is 680 yards long, 6 feet 6 inches high, and 5 feet 6 inches wide, and contains one 18-inch gas main, one 10-inch water main, and one 6-inch water main. The positions of all intersecting streets are indicated by names on plates fixed to the wall. The work of constructing this subway, together with the laying of the gas and water mains and tram lines, and paving of the streets, was carried on simultaneously, and cost 7*l.* 2*s.* 4*d.* per lineal yard, inclusive of lateral ways and the electric lighting throughout.

THERMOMETRICAL READINGS.

It is possible that there may be doubts as to the effect of a severe frost on the water pipes in the subway. By the courtesy of Mr. Arthur Brown, M. Inst. C.E., the author is enabled to give the results of the maximum, minimum, and 10 o'clock a.m.

Date.	Subway, Albert Street.			Water Offices, Albert Street.			Castle Museum.			
	Max.	Min.	Pres. Temp.	Max.	Min.	Pres. Temp.	Max.	Min.	Pres. Temp.	Min. on Grass.
1892										
Jan. 13	48·0	42·5	..	39·1	27·0	..	39·2	23·7	34·9	24·5
„ 14	44·2	42·0	43·0	37·0	29·0	32·8	37·2	28·9	30·9	29·3
„ 15	44·2	42·0	42·3	34·8	28·0	30·8	32·8	27·0	27·8	26·2
„ 16	43·4	40·7	41·3	33·5	22·0	26·0	33·1	19·4	25·0	22·4
„ 17 and 18	43·0	41·0	42·8	37·3	25·4	36·0	36·9	23·8	36·9	24·5
Jan. 19	43·5	41·8	42·5	39·6	35·6	36·0	39·2	33·6	34·7	33·2
„ 20	43·2	41·9	42·4	37·8	33·0	34·5	35·8	32·0	33·3	31·5
„ 21	43·1	42·0	42·4	37·3	33·6	35·5	35·8	32·0	32·9	31·2
„ 22	43·2	42·0	42·8	40·7	34·5	40·0	40·8	32·0	39·3	30·9
„ 23	43·5	42·4	43·0	42·2	37·0	41·8	41·9	35·5	41·9	30·4
„ 24 and 25	43·8	42·8	43·2	45·6	35·3	38·4	46·1	35·0	38·7	29·7
Jan. 26	43·9	42·8	43·0	43·5	31·7	34·2	44·6	30·5	33·2	25·4
„ 27	44·3	43·0	44·0	46·5	34·0	46·0	46·1	32·2	46·1	30·7
„ 28	44·8	43·0	43·5	47·8	38·0	40·8	46·4	37·8	38·7	30·7
„ 29	45·1	43·7	44·3	52·5	35·4	52·0	52·8	37·8	52·8	36·7
„ 30	45·7	44·0	45·0	53·3	36·3	51·0	52·7	47·0	50·1	42·5
„ 31 and Feb. 1	45·8	44·3	45·3	53·1	40·6	47·0	53·3	40·2	46·1	33·8
Feb. 2	46·0	44·0	44·0	48·3	34·0	36·8	48·0	33·5	36·5	29·9
„ 3	45·1	43·8	44·6	41·2	32·0	40·0	40·5	34·3	39·7	30·2
„ 4	45·3	43·2	44·0	42·1	30·0	33·5	42·5	28·4	32·2	24·5
„ 5	45·3	44·0	44·5	43·0	32·6	43·0	42·6	31·3	42·4	29·2
„ 6	45·3	44·2	44·8	46·0	37·8	42·7	46·2	39·6	42·1	30·9
„ 7 and 8	45·8	44·5	45·0	53·4	35·0	45·8	54·5	41·0	43·9	37·7
Feb. 9	46·1	45·0	45·4	49·3	38·0	44·5	49·1	35.2	42·9	33·5
„ 10	46·2	45·2	45·8	48·9	43·8	46·5	49·0	41·8	46·0	37·7
„ 11	46·6	45·3	45·8	49·3	39·0	41·5	50·5	37·3	40·0	30·7
„ 12	46·7	44·5	45·5	49·8	33·7	40·0	52·1	31·7	38·6	24·1
„ 13	46·5	45·2	45·4	46·1	36·8	40·0	47·7	35·8	38·3	30·3

temperatures inside the Albert Street subway, Nottingham, and the corresponding readings outside the subway, together with the maximum, minimum, and 9 a.m. temperature at the Observatory at Nottingham Castle, taken in 1892. Owing to the immense number of figures to be dealt with as a whole, the author has thought it sufficient, for the purpose of showing that there is not the least chance of the temperature in subways going down to anywhere near freezing point, to tabulate the readings taken for a month.

Utility of Subways.

Corporate and other authorities having jurisdiction over the streets and highways, are slow to recognise the value of a subway for underground pipes. By their construction every access can be obtained, for the purpose of inspection, alterations or additions, to any of the sewers, gas and water mains, connections, and other pipes at present beyond inspection.

All fire hydrants (which it is imperative under Sec. 66, P.H. Act, 1875, for Local Authorities to provide), valves, house connections, and their pipes, could be inspected at any time of the day or night, repaired, renewed, or lengthened, without disturbing the carriageway or interrupting the street traffic. An efficient system of detection and prevention of water pollution or waste would be provided, the waste of water in certain districts being of the utmost importance. The life of iron pipes would be considerably increased, and in the author's opinion the water would be kept much cooler in pipes placed in a subway, than when surrounded by earth. Electric and telegraph wires need no longer be run on poles and roof fixtures, the circuits could be put underground, rendering them less dangerous and more reliable and permanent.

Suggested Construction.

In these days, when cost is often too prominent an object, it becomes necessary for the engineer to weigh the bad materials and the good, the cheap and the costly, and to ascertain their relative value for the work for which they are to be used, and to see if the expensive material is really worth its extra cost for the work. The author, after due consideration, and having had considerable experience in concrete work, suggests that such subways should be constructed wholly of concrete.

The practical value of concrete is exemplified by its extensive use in connection with reservoir embankments, viaducts, piers, bacteria tanks, sea walls, coast defences, groynes, sewers, and foundations generally. The foundation for the new Admiralty buildings which cost, the author believes, about 23,000*l.*, afford an example of its use on a large scale. The author is satisfied that there is no material equal to it either as regards economy of cost, capability of resistance, rapidity of execution, or for hardening with age when properly made and placed *in situ.* It is eminently adapted for positions where great resistance to compression is required. It is inexpensive as compared with many other materials of equal strength and durability, and it is capable of being made from any suitable material at hand.

The subway would have a corresponding inclination with the surface of the street, the floor being laid with cement concrete, and drained at frequent intervals by means of trapped gullies connected with the sewer; these gullies would receive any waste from the water main in case of a burst occurring. In the adoption of a subway similar to that shown at Fig. 3, it would be necessary to construct lateral ways at intervals along the street, and where there are extensive buildings a lateral way would be required for every other building to carry its connections through; this would materially add to the constructional cost. In some of the metropolitan boroughs it might be advisable to excavate the whole width of the street, and form one large subway, or subways, but the author is now treating more particularly of suburban districts where the same difficulty is experienced in dealing with underground pipes and the breaking up of the streets.

For new streets the author proposes to construct two small subways as illustrated at Fig. 4, one under each footpath, through which would be laid the gas and water mains, electric and telephone cables, the concrete being perforated with 2 or 2½-inch holes for the house services, thus obviating the construction of lateral ways. The foul and surface water sewer would be placed under the roadway with the usual manholes, being on the same principle adopted in the present day with the addition of elongated eyes, say every 20 feet, extending to each subway. The chamber (common to all house drainage) would be constructed in the bottom of the subway by, and at the cost of each owner when requiring to connect to the sewer, the necessary provision being made for disconnection and ventilation of the house drain to conform to the local bylaws.

The Public Health Act, 1895, authorises the making of by-laws with respect to sewerage of new streets, but in reference to this the Local Government Board, in their circular letter, dated 25th July, 1877, when the model by-laws were published, explained the circumstances which led to the omission of by-laws on that subject from their model series.

The author considers that a small subway of specified size under each path similar to his design illustrated at Fig. 4, for a 40-feet street should form a part of the laying out of each street, as, if such subways were constructed simultaneously with the laying out of the street the additional cost would not be great, and if the surplus necessary to be removed was in sand or gravel, such surplus would form a good credit. The gas and water main being in duplicate might prove advantageous, rather than detrimental to the two subways proposed.

Whatever class of subway is adopted, a point of considerable importance would be to make the best use of every portion of available space. The author has specially designed and illustrated, at Fig. 3, suitable iron brackets for this or a larger subway, to carry 8-inch, 6-inch, and 4-inch water and gas mains, with spaces through the body of the bracket adaptable for wires if found necessary. The top ledge is prepared to receive a number of small pipes to contain telegraph and telephone cables. Necessary provision would be required for the lugs of these brackets to be built into the concrete as the work proceeds.

In the actual designing and constructing of a subway there are many engineering and other details that can only be decided upon under the circumstances and difficulties affecting each individual case.

ENTRANCES.

In the construction of a subway to the design illustrated at Fig. 3 provision is made for side entrances being constructed on the footpath as a means of access. The details of construction are similar to those required for a large manhole upon a brick or pipe sewer, being built in concrete, or, if preferable, 14-inch brickwork executed on the trough system, all the bricks being laid first to break joint horizontally with the middle course, the cavity between having a good layer of cement mortar, each brick being well bedded. By this method the length of the horizontal joint is increased by several inches, and brickwork constructed thus has been found practically watertight, requiring no rendering.

The opening to the path would be covered with Hayward prism lights and patent balanced flap, provision being made for protection during use. From these entrances to the subway lateral ways about 3 feet wide by 5 feet high would be necessary. In smaller subways an ordinary manhole would serve as access, but would be specially designed so as to readily admit a standard length of pipe of any size, or in the case of double subways it might be possible for arrangements to be made whereby access could be gained from one of the areas through a suitable door.

In dealing with large cities and busy thoroughfares, or wide streets where foot passengers find difficulty in crossing the streets on account of the traffic, the author considers that, in conjunction with the construction of the subway, additional underground conveniences should form a part of the scheme, so planned that an easy and ready (but private) access could be gained from the first landing of the entrance to the underground convenience, thus proving a more serviceable entrance for the men, the pipes and their accessories.

It will be observed that in Fig. 3 the approach to the subway is shown by spiral stairs, as the author considers where large subways are constructed and a considerable expenditure entailed, the approach should be such as to allow any ratepayer to descend for inspection of the interior, but where the subways are on such a small scale as that shown at Figs. 2 and 4, this is a question which need not receive consideration.

Lighting.

For a large subway the author would recommend the lighting throughout to be by electricity, care being exercised that all fittings are water and air tight. A subway of similar construction and size to that shown at Fig. 3 would require 136 16-candle power lamps fixed along either side of the roof, assuming the length to be 2000 feet, each side having 68 lamps at 30 feet distance apart, and fixed intermediately. These lights would be switched on the corridor system. Every 10 lights would have two double contact switches, one to be placed at either end of the row of 10 lights on the side of the subway, thus enabling a person to enter at one end of the subway and switch on 10 lights, and go to the end of that row of 10 lights and switch them off, and switch the next row of 10 lights on, and so on through the subway. Every 10 lights would have a separate circuit to be run to distribution fuse board at the end of the subway. The whole would be governed by a main switch and fuse at the end of the subway.

The wiring would be run in simplex enamelled screwed steel conduit, and all joints would be painted with red lead.

The switches should be simplex, water-tight, and the lamp fittings to be simplex subway water-tight lanterns. Plugs should be fixed on either side of the subway about every 10 feet, and placed intermediately. These plugs would run out in two circuits to distribution fuse board. Hand lamps should also be provided with wire guard, to have about 70 feet of extra insulated workshop flexible wire connected to them. For small subways Hayward's semi-prism lights might be found sufficient, if safety lamps were used by the men when at work in the subway.

Ventilation.

One of the most important matters connected with any underground passage or subway is the condition of the atmosphere enjoyed, or suffered, as the case may be, by those who have to work therein. On such works as these, and in a paper like the present, it will not be expected that some new ventilating theory should be advanced. Ventilation is an absolute necessity, and the simplest method appears to be by small chambers built up to the surface of the street, with open gratings at intervals of about 40 yards.

Cost.

Cost is a very important item in the consideration of the undertaking, but it is almost an impossibility to give any intelligent or reliable price for underground or subway construction. It depends entirely upon local conditions, and, besides this, within the last few years a very considerable increase has taken place in the cost of material and labour.

Information given in a preceding section of the cost of construction of existing subways is of but little practical value, and for all purposes must be accepted with the greatest caution, as it is impossible to make useful comparison between the cost of construction at other places without knowledge of the circumstances of each incidental work, such as excavation and nature of ground. In the present day the unit of cost is now considerably greater than what would have been found sufficient a comparatively short time ago.

In any case the initial cost will be heavy, and in some cases the ground may be treacherous and close timbering rendered necessary. On the other hand, some compensation may be obtained by excavated material being suitable for the concrete work. The additional cost entailed in laying out a new street with two subways, as illustrated in Fig. 4, would be about 2*l.*

per lineal yard for the subway proper, the laying of the gas and water mains and sewer being common to any new street. This additional cost might be defrayed by the local authority or taken into consideration under Section 10 (*b*), Private Street Works Act, 1892, due allowance being made in settling the apportionment.

The author's contention is that the increased facilities which would result, both for business and pleasure purposes, and the relief from the presence of an army of men with picks riving up the roads, day after day, should commend themselves as the principal factors, and the question of expenditure should be a secondary consideration.

Revenue.

The author is of the opinion that where subways are contemplated in old thoroughfares the cost, charges and expenses incurred should be defrayed by a loan granted by the Local Government Board, spread over a period of from thirty to fifty years, these coming in the category of permanent works. A charge could be made for electric or telephone wires or any pipes belonging to a company.

A contract between a council and a gas company which gave the company leave to open a street provided they made good the surface and paid 1*s*. per yard of road broken up, was held to be valid and not illegal. A rental of 1*s*. per annum in respect of each yard of pipes laid in the subway (such rental to be irrespective of any rating or assessment to the parochial rates) would therefore bring in a small return. It is only reasonable that some charge should be made or rental received from the companies whose mains traversed the subway, and who would be relieved of the expense at present incurred in repairing and reinstating the road surface. For telegraph and other wires, as under Section 17 of the Telegraph Act, 1863 (and similar provision in other Acts), the companies are also liable to pay all reasonable expenses to which the authority is put on account of the superintendence of the breaking up of a street.

If, in conjunction with the construction of large subways in busy thoroughfares, underground conveniences formed a part of the scheme, and were made to serve as entrances, the receipt from the fees chargeable for the use of water-closets under the Public Health (Amendment) Act, 1890, would yield a good return, as much as from 200*l*. to 1000*l*. per annum having been cleared as profit for such accommodation. The author believes as much as 2000*l*. per annum has been realised from the conveniences in Piccadilly Circus.

ROBERTS' COLLAPSIBLE CENTRING.

Turning next to constructive details, the author would first direct attention to Roberts' collapsible centering as shown at Fig. 5, which is specially designed to suit the author's system of subway. It is similar in principle to Roberts' circular and egg-shaped centrings, and consists of a central screw with right-hand threads cut on one-half its length, and left-hand threads on the other half. Nuts, having top and bottom legs for top and bottom vertical arms, and sockets for horizontal arms, fit on the screw; the vertical arms fit and work in top channel irons. To the top channel is hinged on each side a frame covered on top with a thin plate or wood (the latter is preferred for brick arches, as the plate gets indented when bricks are thrown or dropped on it), and bent to the radius of the arch of the subway.

The outer side of the frame is kept in position by the horizontal arms, which work in a ball-and-socket joint. A bracket is attached to the central screw at each end, to which the trolley-wheel axles are fixed. The front axle has a slight movement, and is fitted with a handle-bar so as to guide the centering while being pushed from one position to another. Owing to the floor being higher on one side than the other, the axle is made Z-shape, and is guided between two angles fixed on the light girder on the deep side. The axles are also so guided that the wheels remain always the same distance from the vertical centre of the centring. The vertical arms are attached at the bottom to an angle iron on the high level side, and to the top of a light girder on the low side, and these are joined together by distance-pieces.

The *modus operandi* is as follows: The illustration shows the centre in position ready for a layer of concrete to be laid on from each side in toward the centre, and when consolidated another layer of concrete or other material can be put on. In this position it will be noticed the wheels are clear of the floor, and the whole weight is taken by the longitudinal angle and girder, and the vertical arms are nearly in a vertical position. When the concrete arch is completed, the handles attached to the ends of the central screw shaft are turned so as to bring the nuts out. In doing so the top channel iron comes down, and the segmental plates attached to it close in towards the centre screw shaft. The screw also descends until the wheels rest on the floor, when the bottom angle and girder rise clear of the floor.

The whole centring can then be run forward on the trolley wheels clear of the top arch, and kept in the centre of the subway by the lever attached to the axle of the front set of wheels, when moved forward leaving about a foot of the centering under the arch already constructed. The handles at the end of the shaft are turned in the opposite direction, which opens out the centring, raises the wheels and lowers the bottom angle and girder to rest on the floor, and all is ready for the concrete to be put on, to add another length of arch to the subway.

As the time taken in contracting, moving the centring to a fresh position and expanding again, is very little, the speed at which subways can be built depends almost entirely upon the time taken to complete the arch. A 36-feet length of brick arch 7 feet 6 inches diameter has been done per day with these centres, and as concrete could be laid much quicker than brickwork, the out-turn would be greater. The time taken in moving an ordinary centre and adjusting it is saved.

Composition of Concrete.

The strength of concrete varies within considerable limits according to the quality and relative quantities and nature of the aggregate and cementitious material employed. Faulty cement, dirty sand, soft aggregate, and careless manipulation or mixing, are dangers requiring to be guarded against, or a considerable amount of material may be spoilt.

The average crushing weight for concrete composed of 1 part Portland cement to 6 parts aggregate is from 80 to 100 tons per foot super for concrete twelve months old, and from 15 to 25 tons per foot super one month old, and at the end of four months is not more than 15 per cent. below the strength of neat cement, and this difference continues with a tendency to diminish as the age of both increases. This favourable result is, no doubt, to a great extent due to the inherent strength of the aggregate, and the capital bite that it affords to the matrix. The selection of the aggregate has generally to be governed by the materials best obtainable in the locality.

The object generally aimed at in proportioning the ingredients is to secure an aggregate containing the least possible quantity of interstices. A simple method adopted by the author for this purpose is to fill a water-tight box of known capacity with damp aggregate, shaking it well during the operation, and then pouring into the box sufficient water to fill it to the brim, the quantity of water being the measure of the interstices in the aggregate. The least quantity of interstices is in the aggregate containing pieces varying in size.

Good screened gravel and shingle contain an average of 33 per cent., while broken stone may contain as much as 50 per cent. of interstices. As it is essential in these constructional works to have the concrete impervious, the percentage of interstices in both the aggregate and sand is very important. The size of the aggregate used for forming the floor of the subway should not exceed one inch, largest diameter. For all other concretes the maximum diameter should not exceed in any direction two inches, with a minimum diameter of a quarter of an inch.

In the author's opinion, no material is better suited for matrix than Portland cement, the superior setting qualities and great strength allowing a much larger proportion of the aggregate to be used. As regards the proportion of sand, the least possible quantity should be used, but sufficient to fill the interstices and form a compact mass when the whole is bound together by cement.

The author considers great care should be exercised in using sea sand, owing to being deficient in sharpness and containing alkaline salts; there is also, in his opinion, a tendency for nitrification setting in and weakening the work. Washing the sand adds a very large percentage to the strength of the concrete.

The proportions recommended to produce a good solid concrete are as follows:—

For arches and side walls: 1 part by measure Portland cement; 1½ parts do. sand; 5 parts do. stones.

For the same where the backing is rock or of a firm nature: 1 part by measure Portland cement; 2 parts do. sand; 6 parts do. stones.

TESTING CEMENT.

The object of cement testing is to obtain a forecast as to the strength and soundness likely to follow after a lapse of time. All cement used on such important works as these should be subject to inspection and rigorous tests under standard conditions, preference being given to that which by their record show a tendency to develop strength steadily for long periods. Although there is a diversity of opinion upon the tensile and other standards advisable to adopt, it is very important that some careful and reliable method of testing the cement upon which the stability and durability of the superstructure depend should be followed.

The author considers the cement manufacturers should be made aware that their cement may at any moment be subjected to examination on—(*a*) Specific gravity; (*b*) Tensile strain; (*c*) Transverse breaking weight; and (*d*) Fineness and weight. The latter because the finer a cement is ground, the less it will weigh, and at the same time be much stronger, so that it is more practicable that its weight and fineness should be observed together and judged by its specific gravity instead of in lbs. per striked bushel, which appears to be the method usually adopted. It is open to doubt if a cement standing a tensile strain of 350 lb. to the square inch when tested on a section of 2¼ square inches area seven days after immersion in water, is sufficient evidence to prove its stability.

Mixing Concrete.

The merit of the constructional works under consideration depends entirely upon the care exercised in the mixing of the concrete. The perusal of specifications by different engineers shows that the proportions in which the materials are to be mixed vary so much that there is not a standard specification of requirement. Unfortunately, it is not every specification that is as definite as the following:—

All concrete used upon the works shall be properly gauged with stone sand, and cement, being each separately measured. It may be thought by some that this is a detail of little importance, but in the author's opinion it is of great importance. Concrete specified to be of Portland cement, sand and gravel in the proportion of 1 to 8 might in reality turn out to be 1 to 11 if the contractor measured the sand and stones together in a box having eight times the capacity of the box in which the cement was measured, the large box, when filled to the top with stones, would contain from 30 to 40 per cent. of interstices between the stones, and to effect a saving he could fill these interstices with sand, the concrete thus consisting of 1 part cement and about 3 parts sand and 8 parts stones—a very different interpretation to that intended by the engineer when drawing up his specification. Another point of consideration is whether the material should be put in layers and rammed, the surface being picked up before the next layer is put in. The author's experience is that, however much care may be taken in following that course, the second layer will not form a homogeneous mass with the first.

In forming the arches, if the whole of the material is not put in at one operation the weakening of the corbel and upper portion of arch will result from the concrete being put in in layers (see Fig. 6). Fig. 7 illustrates radiating joints forming an arch proper, which can be executed by taking a little care.

In mixing concrete it is false economy to throw the water upon the mixture from buckets; this mode wastes water and washes away a large proportion of the cement. About 40 gallons of water usually suffices for every cubic yard, but the quantity must be determined by the class and condition of the aggregate and the state of the atmosphere. Generally speaking, when mixed with water the bulk of cement is reduced 10 per cent., and sand 20 per cent. For mixing concrete the author recommends the portable gravity mixer, which is in use on several large contracts, and is finding favour generally as an efficient mixer and an economiser of labour.

Conclusion.

It appears to the author that the whole question of the construction of subways for the reception of all underground pipes resolves itself under three heads: Is it necessary, advisable, or economical?

In this paper the author has endeavoured to avoid making suggestions which appear simple, easy, and practicable on paper, but which, when put to the test, are found wanting. He fully recognises that the undertakings advocated by him would, in many of our large and busy thoroughfares, require great forethought, as it is possible that difficulties of the most formidable character might be encountered, but the tact of the engineer would enable him to overcome the natural obstructions that presented themselves, whilst the difficulties met with would be the means of enabling him to utilise to the fullest possible extent his knowledge and skill.

The public mind may not be disposed to class the silent and hidden subways containing the pipes conveying materials necessary for our very existence, as engineering triumphs; but, recognising the manifold difficulties attendant upon the carrying out of such an undertaking in a large city or town, credit is certainly due to the municipal engineer by whose skill and energy such works are created.

DISCUSSION.

The PRESIDENT stated that, owing to a serious illness, Mr. Allen was unable to be present, hence the paper had been read by the Secretary. The President, however, had much pleasure in proposing a vote of thanks to the author for his paper, which thanks would be communicated to him.

He would now make a few remarks, as the subject was one in which he took a great interest, having on a previous occasion himself read a paper on the subject before the Society. He thought that none of the members would disagree as to the importance of providing subways in our large towns. But the difficulties of construction were known only to those who had carried out such work. Mr. Allen's paper appeared to refer mainly to subways in suburban streets or smaller towns, but the necessities of large towns of course were greater, and in his (the speaker's) opinion a different method of construction was required.

To municipal engineers it was a grievous thing to see the street pavements pulled up as they were continually, day by day, and almost hour by hour, by people engaged in laying down the various services for water, gas and other conduits. Personally, he had taken great pride in those streets of the metropolis in the district of Charing Cross, which were formerly under his charge. It was a cruel thing to see a freshly-paved and perfectly formed street surface ripped up from end to end by some Company having special powers under Acts of Parliament, and the municipal engineer could only look on and abide by the results and see his work ruined, knowing all the time that it would remain spoilt for the next six or seven years, as a pavement thus mutilated could never be restored completely. And who gets the blame for this state of affairs? not the responsible man, but the local surveyor, who was thus placed in a most unsatisfactory position with regard to the public.

Mr. Allen mentions one or two towns in England—Nottingham, for instance—as the pioneers of subways. He (the President) knew the Nottingham subways very well, and he observed that Mr. Blair, of St. Pancras, was present, and who had also been connected with them. He hoped that that gentleman would join in the discussion and give the meeting some information. Side vaults had been mentioned in connection with the Nottingham subways, and the author had referred to the subway entrance being through them. That was not the case, as the entrance was entirely distinct from the side vaults, which were only accessible to adjoining owners, who rented them from the Corporation.

Again, Mr. Allen said that the ratepayers ought to have access to the subways. He (the President) totally disagreed with that view. If the public at large were to have access to the subways, it would be necessary to have a bevy of policemen on duty there.

The question of steam-rollers had been touched upon, pipes being very often broken by their use on the roads. Some years ago he had a case exactly similar to the one mentioned in the paper, in which an explosion of gas occurred in consequence of a leakage from a service-pipe which was broken by a steam-roller. The leakage was not discovered until the explosion had occurred and serious damage done to the premises. He thought that the design in Fig. 4, showing a subway under the pavement, was the one best adapted for country work and provincial towns. But he was thoroughly convinced that for towns like London, Liverpool, Manchester, or Birmingham, the subway should have the whole width of the roadway.

The estimates given by Mr. Allen were very small in comparison with the figures which he (the President) gave some years ago. Of course the question of cost depended upon a thousand and one conditions and details connected with the streets or roads through which the subways were taken, and also upon the cost of the materials of which the subway was constructed. Therefore it was impossible to give anything more than an approximate guide as to cost. The prime issue of the paper was the use of concrete for the construction, apart from any other materials. In the question of cost, Mr. Allen had introduced underground conveniences. He (the speaker) did not see how these could be attached to subways, and, in his opinion, the author appeared to be stretching a point in order to get some return from the conveniences a an asset for the subways.

Before calling upon anyone to open the discussion, he would ask the meeting to hear a communication by Mr. Percy Griffith, on the subject of concrete construction, as carried out in a town in the United States.

The vote of thanks was carried unanimously.

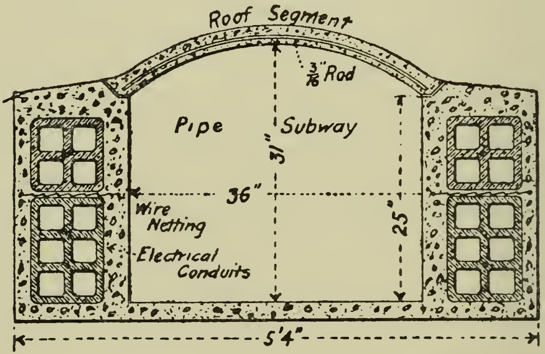
The Secretary said that he should have much pleasure in conveying the vote of thanks to the author, who was unfortunately prevented from being present by sudden illness.

Concrete Conduit Construction.

The following description of concrete conduit construction, carried out in the City of Bloomington, Illinois, U.S.A., which appeared in the 'Engineering News' (New York) of April 18, 1901, was then communicated by Mr. Percy Griffith, Vice-President.

The City of Bloomington, Illinois, is to have two competitive systems of heating by distribution from a central plant. It already has in operation a hot-water heating-plant on the Yaryan system, and the Consumers' Heat and Electric Company is now putting in a plant for heating buildings, etc., by means of the exhaust steam from its power-station. To carry the pipes and the electric wires this company has adopted a novel form of concrete conduit or subway construction, which is illustrated in the accompanying cross section.

It consists essentially of a floor and side walls of concrete with two lines of hollow-tile electrical conduit embedded in each of the side walls. The space between the walls forms the pipe-subway, and is covered by segmental arch-plates of Monier steel-concrete construction, resting upon skew-backs formed in the upper corners of the walls.



In each wall is a line of six-duct vitrified clay salt-glazed conduit laid on its narrow side, and a superimposed line of four-duct conduit, all being laid with broken joints and surrounded with Portland cement concrete. This makes a system of ten electric ducts on each side of the central pipe duct. One side is intended for telephone and telegraph wires, and the other for electric light and power wires. The twenty electrical ducts are $3\frac{1}{4}$ inches square in the clear.

The pipe subway is 36 inches wide with a height of 30 inches at the centre and 25 inches at the sides. The entire width of the structure is 5 feet 4 inches. The pipe subway will contain one 12-inch exhaust steam main, one 6-inch live steam main, and two 4-inch return pipes. These are all insulated with magnesia pipe-covering, and provided with expansion joints, roller bearings, etc.

The vitrified clay conduit is of the usual multiple-duct form, being in lengths of 3 feet, and alignment being secured by steel dowel pin-connections in the joints. The joints, though very close, are wrapped with burlap as a precaution against the entrance of cement mortar from the concrete. The two lines of conduit in each side are separated by a thin coat of cement mortar, in which is embedded a net of wire mesh that serves as a tie for the thin inner and outer vertical sections of concrete. This tie is considered hardly necessary, but is inserted to ensure ample strength. No dependence was placed upon the adhesion of the concrete to the clay tile, although a bond developed to an unexpected degree of strength. There are only 3·25 cubic feet of concrete per linear foot of subway, exclusive of the roof. The concrete was mixed in proportions of 1 part Portland cement, 3 parts torpedo sand, and 5 parts crushed limestone. A hand-power drum mixing-machine was first used, but was afterwards discarded for hand-labour, the volume of concrete being so small in proportion to the entire work that there was no economy found in the use of the mixer. During very cold weather the cement, sand and stone were heated, and a small proportion of salt was mixed with the water.

One of the most striking features of the subway is the roof of Monier construction, which consists of arch plates with a clear span of 3 feet, and a rise of 6 inches. The plates are 2 inches thick, with curved $\frac{3}{16}$-inch steel rods embedded in the cement mortar, which is composed of 1 part vulcanite cement and 3 parts torpedo sand. As the work was done during freezing weather, the Monier plates were made under cover in a warehouse, and transported to the location of the work when needed. They were easily handled and set in place by two men. By this method no centring was needed in the trench, and it was possible to place the backfilling immediately after the placing of the arch plates. The absence of centring for the tunnel roof greatly facilitated the progress of the work. Disregarding the element of time saved, the small space left between the steam pipes and the roof would have made the use of centring for ordinary construction a matter of difficulty and expense.

The total length of the conduit will, when completed, be approximately 5000 feet, traversing the central portions of Bloomington; about 1300 feet have already been laid. The engineer in charge is Mr. Chas. G. Armstrong, of Chicago. The contractors are Hoeffer and Co., also of Chicago.

Mr. Percy Griffith said that he should like to explain with regard to the description he had just read, that it occurred to him when it came under his notice that as an example of American practice it would afford interesting matter for discussion. He confessed to feeling that a subway which gave no room for anyone to get along it, even without any pipes, would hardly meet the necessities of the case as brought forward by Mr. Allen.

With reference to Mr. Allen's paper he should like to call attention to one point which had been mentioned by the President, and that was the laying of pipes being generally in the hands of companies, while the roadways were, of course, in the hands of local authorities. Undoubtedly friction often took place between the two, but he thought the tenor of the President's remarks showed a tendency to be critical of the way that companies usually carried out the necessary operations connected with their mains. It was only fair in this connection to call attention to the inconvenience which had been suffered in London during the last five months in connection with the laying of telephone wires, which work was being carried out, not even by a local authority, but by the Government itself. It must be obvious that all work of that sort was done mainly, if not entirely, in the public interest; and, although it might be said that in the one case the work was carried out in order to enable a company to make a dividend, it must be remembered, on the other hand, that without the efficient maintenance of the main communications the consumers would not be properly served, and the authority responsible for them would be liable to very serious blame. The inconvenience was one which the public must put up with until they could get some general system of conduit construction carried out.

He thought that there was another point in connection with the paper which was worthy of notice, and that was that in any but new streets the public convenience of the subway was largely discounted by the enormous inconvenience entailed in the construction of it; and, therefore, he feared that the construction of subways in any but new streets was almost out of the question. He thought, however, that the whole question might be considered, not only from the point of view of public convenience, but from a financial point of view, in the same manner as were other engineering undertakings producing a revenue. The author had remarked that rentals could be charged for the use of subways, but he did not say very definitely what was the total amount of the revenue obtainable in that way. He (the speaker) thought that if they could estimate the financial advantage to any company or local authority using a subway instead of having to break up and afterwards repair the streets, whenever they required to lay, repair or extend their mains, they could see to what extent the available rental would justify the total outlay required.

The author mentioned in his paper some four or five places in regard to which he gave the number of openings of the road. He would like to ask the author what period was represented by those figures. Apparently it was one year, since the quotations were from an annual report, but, if that were so, it would be interesting to know to what year the author referred. He was also desirous to know why the author had selected the places that he had selected, as that might throw considerable light upon the matter dealt with in the paper. If the author or any member present could give some information with regard to the revenue obtainable from subways, he was sure that the information would be very interesting and instructive.

Mr. J. Patten Barber said that he had on a previous occasion expressed his views upon the convenience which would be afforded by subways in all the principal thoroughfares. If they would only get rid of the frequent opening of the streets, one would be delighted to have subways. He had often been disappointed with the way in which the roads which he was responsible for maintaining in a satisfactory condition had been cut up and damaged, either permanently or for a considerable time, by repeated openings. It was very distressing to find that one's roads were interfered with so frequently by the companies which had powers to open them. The damage to the roads might be considerably reduced if the companies would only see that the roads were properly re-instated. The London navvy had not much respect for the roads which he opened. And, if he did any ramming after the filling up, it was probably because his time for leaving off had not arrived, and he must fill up the remainder of the day. As a rule, the ramming was by no means efficiently done, and the result was, that when a trench of about eighteen inches wide was filled in, a miniature tumulus some six feet wide and nine inches high was left on the surface of the road. A great deal of the damage caused by the opening of the roads might be avoided if the men would only use reasonable care in filling in. But, until subways were made, there would always be annoyance to the public through the continual opening of the roads, and of course there would be the usual cry, "How is it that we do not have subways?" People were always calling out for subways, but they did not seem to be any nearer to getting them.

Unfortunately, subways could not be constructed without a considerable expenditure being involved, and, after all, that was the essence of the question. Who was to pay for subways?

Where was the money to come from to defray the cost of constructing subways in order that the public might have what they wanted, namely, freedom of traffic through the streets without being impeded and annoyed in the way they were at present? However well the companies might do their work in opening and refilling, the annoyance to the public would continue. Manifestly it would be unfair that the companies which would have to use the subways should pay the whole cost. He apprehended that there would have to be a kind of mutual arrangement between the companies and the local authorities to defray the cost of construction.

But then there were the existing mains under the streets, which would have to be brought into the subways, and the removal of these would involve an enormous expenditure, besides a great interference with the street while the mains were being put into the subways. The subject was not such an easy one as it was thought to be by most of the people who only talked about it. Those who endeavoured to solve the problem were face to face with the great difficulty of expenditure, and for his own part he did not see how subways were to be got unless they were constructed at the joint expense of the local authorities and the parties who used them. Whether anything could be done by utilising convict labour or something of the kind, he could not say. But it was quite certain that the ratepayer would continue to grumble about his streets being cut up, and he was also quite certain that the ratepayer would never willingly pay the bill for constructing subways.

The cost which Mr. Allen gave for the subway which he suggested, namely 2*l.* a linear yard, was, he was afraid, rather misleading, unless it was to be taken that the subway was to be put into a soil which was mainly gravel and which could be used for the concrete. If the subway was to be put into a clay soil, such as that of London, every cubic yard which was dug up having to be taken away, and every cubic yard of material for the concrete having to be brought to the site, he was quite certain that the work could not be carried out for anything like 2*l.* a yard run.

Mr. Allen had gone into other matters which hardly related to the main subject of subways, except as to their construction. He did not think that any engineer who wished to produce good concrete at the present day would so loosely word a specification as to say that the concrete was to be composed of cement, and so on, in the proportion of 1 to 8, if he had to construct a subway or any work of importance. An engineer who knew anything about what he was doing would take care to specify the exact proportions of the materials that he wished to be used for his concrete, instead of adopting such a loose way as describing them as "cement, gravel, and so on, to be mixed together in the proportion of 1 to 8."

Mr. Allen was, he thought, quite right in his view as to the composition of the concrete which should be used in this case. Unfortunately, specifications for concrete were very loosely drawn, the result being that concrete did not get the credit for being a good material that it ought to get. Concrete, with proper ingredients properly mixed, was undoubtedly the best, cheapest, and most convenient material to be used for subways.

Mr. William Nisbet Blair said that it was rather a pity that he should follow immediately at the heels of Mr. Barber, seeing that both he and Mr. Barber were placed in a similar position with regard to public works. Previous speakers had referred to the difficulty of constructing subways in existing streets. From the tone of the paper he judged that the author was not familiar with London, but if he had been so he would have realised that, with the multitude of pipes which now occupied the roads, and belonging to companies of all sorts and characters, it would be absolutely impracticable to excavate for a 14-foot subway, and that was the very least size which would be of any use whatever. It would be also impracticable to adopt the larger suggestion, namely, that the whole carriage way should be converted into a subway. Obviously the traffic would have to be diverted, very much to the inconvenience of the tradesmen in the street.

It would be found that all streets in which subways had been made were new streets which had been made through a cleared area. The new street which was being made from Holborn to the Strand was a case in which, obviously, it would be wisdom to make an ample subway, and in which the money would be well spent. But take Cheapside, for example. Who would talk of constructing a subway there? A subway was not a thing which could be made at a great depth like a tube railway, but it was bound to be on the top in order that the pipes might be reasonably convenient to the houses. In nine out of ten of the existing streets in the large towns it would be quite impracticable to construct subways. As to the remaining streets, those in which subways would be practicable, they would be suburban streets in which, according to his view, subways were not needed, for they would not, within a measurable time, alter their character very much. All that was necessary in such cases was a gas main and a water main laid under each footway, in order that the companies might avoid opening the carriageway for every service into a house. That was a very wise provision. The pipes were small in size, and were laid under a footway with a York paving, which was easily relaid. Even if an electric cable was thrown in, there would only be three services on the footway on each side.

With regard to cost, he did not wish to question the accuracy of the author's reference to the subways made at Nottingham, but it must be borne in mind that one of those subways was made thirty years ago, and the other about twenty years ago, when the cost of labour and materials was very different from what it was now. Mr. Barber had mentioned the difference that would arise in cost between forming a subway in gravel and forming one in clay. The cartage of every yard of clay cost about 4*s.* For every yard of ballast which was used in the streets they had to pay from 7*s.* 6*d.* to 9*s.* Hence it would be seen that every yard of concrete displacing a yard of clay would involve a primary cost for materials of from 11*s.* to 15*s.* It was evident that they could not excavate the ground and construct a subway such as was shown, for 25*s.* a yard. It would be out of the question.

There were some statements in the paper as to the number of openings which had been made in certain areas during certain periods, and the sums received. In one case, that of Hammersmith, there was a large number of places opened and the expense chargeable was 796*l.* He would assume that figure to be correct. In his district they received for repairs over 12,000*l.* per annum. He mentioned this to give an idea that there was an immensely larger number of openings in some districts than was quoted in the paper.

There was another very important consideration affecting the question. At present there was no power by which a company could be compelled to lay its pipes in a subway, even if a subway were made; and the companies did not like subways. In a previous discussion before this Society the engineer to one of the leading companies stated that it cost a company more to make repairs to their pipes in a subway than it cost to open the ground and make the repairs in that way, owing to the difficulty of getting at the pipes, for with the admission of comparatively few pipes subways very soon become crowded. At an out-of-the-way place like the "Britannia," Camden Town, there was a complete cobweb of pipes under the surface. He had recently had to examine that spot to ascertain what pipes existed there, and he had found that, without making an enormous diversion of pipes, it would be impossible to obtain even a space of about 20 feet by 12 feet as a site for an underground convenience. The difficulty would be still greater in some of the central thoroughfares. And the pipes were increasing both in number and in size. It would be no trifling undertaking to deal with the 30-inch or 36-inch water-mains which were to be found in some places. The bursting of a pipe of such dimensions might bring down the houses in the neighbourhood.

Another thing to be considered was the possibility that some of the men in the employment of the many companies who were allowed to have access to a subway might do malicious damage. If a gas pipe was damaged the escaping gas might be ignited accidentally by a spark from an electric cable or by a formation which was frequently set up in a moist atmosphere where electricity was being conveyed. In his own district cases of gas explosion had occurred in a small electric main conduit into which gas had leaked. What would happen if an explosion of the kind took place in a subway 14 feet by 7 feet?

Mr. D. B. Butler said that a very great advantage was claimed for the use of Roberts's collapsible centring; and the author stated that the speed at which the subways could be built depended almost entirely upon the time taken to complete the arch. Surely the speed depended more upon the time which the concrete took to set, inasmuch as the centring could not be struck until the concrete was sufficiently set to bear its removal with safety. He therefore did not see such an immense advantage in using the collapsible centring in the construction of arches of concrete, though doubtless for brickwork arches its use would result in economy both of time and labour.

He quite agreed with the author as to the strength of concrete varying according to the nature of the materials used. The author said, "faulty cement, dirty sand, soft aggregate, and careless manipulation or mixing, are dangers requiring to be guarded against." Such matters were fairly obvious, but there was another factor which was rarely taken sufficiently into consideration, and that was the effect of extremes of temperature, frost and so forth.

He could not quite uphold the author's objection to using sea-water and sea-sand for concrete purposes. It was well known that cement in sea-water hardened quite as well as in ordinary fresh water, and he therefore did not see why water containing alkaline salts should have any detrimental effect. Probably the author meant that the proper washing of the sand removed, not so much the alkaline salts as earthy or loamy matter, which was the great enemy of cement.

With regard to the testing of cement, he scarcely agreed with the order in which Mr. Allen had put the various tests, if they were intended to be arranged in the order of importance. Specific gravity was put first, but specific gravity by itself was no guide whatever, and if satisfactory in other respects, a cement should never be condemned upon a light specific gravity alone. He would put the soundness of the cement first, in its freedom from disruptive agencies within itself, or what was commonly known as "blowing." A cement might resist a high tensile strain after seven days, but, if it was unsound it contained, so to speak, the seeds of disease, which would eventually cause it to develop cracks and ultimately bring about more or less total disintegration. A tensile test of 350 lb. per square inch after seven days, was extremely moderate, and by itself of little or no use as a criterion, unless taken in conjunction with the other properties of the sample.

He quite agreed with Mr. Allen in objecting to the water being thrown on the cement from buckets. He thought that that was very rarely done now, the more usual custom, and very properly so, being to add it in the form of a spray from a hose or water-can with a rose. It was very unwise to lay down any hard and fast rule as to the quantity of water required for a cubic yard of cement. It depended very much upon the size and porosity of the aggregate and also upon the nature of the cement. It was now generally admitted that concrete when properly mixed should have sufficient plasticity to flow down properly into a solid mass. An excess of water was preferable to a deficiency. In hot summer weather a deficiency of water would endanger a quick-setting cement being "killed" or worked and manipulated after setting had commenced, whereby its strength would be practically ruined.

Mr. HENRY PUPLETT said that as the author referred to only one kind of concrete mixer in his paper, and laid stress on the importance of the proper mixing of the concrete, it would be well to point out that there were other concrete mixers in the market which, by mechanical means, produce a thoroughly mixed concrete at much less cost than any that could be made by hand, and which could be more thoroughly relied upon for uniformity of quality than that made by the only gravity mixer he knew.

Mr. Allen referred to the number of vehicles passing over certain roads; but he (the speaker) thought that if it was intended to make comparisons, the times at which the enumerations were made ought to be given.

Mr. HENRY STOPES said that when he came to the meeting it seemed to him a common-sense view of the matter that, at whatever cost, subways ought to be provided in every street of importance, so that the public should not be subjected to the intolerable nuisance of having the traffic suspended or interrupted while the roads were being opened. But after listening to the discussion he should have some hesitation in venturing to maintain that view. He should certainly like that engineers should let it be known that they were perfectly competent to put subways in every street in which they were desirable, that they did, as engineers, think it desirable to have subways, and that they thought there should be a fair distribution of the cost between the public and the chief users—the various water, gas, electric power and other companies.

It would be to the advantage of the various companies concerned that they should have an opportunity of carrying on their operations with the convenience a subway affords, instead of doing them in the way in which they were done now; and, therefore, the companies should be asked to bear some portion of the cost. He believed that the public would be willing to bear some part of it to avoid such serious interference with the traffic as now took place. He might be looked upon as a person belonging to the twenty-first or twenty-second century; but he should have thought that they could hardly have got beyond the ninteenth century without having discovered so simple a matter as the advantage of a subway. The splendid work which had been recently done between the Bank and the Mansion House in the City, ought to be repeated in every place in which it was for the convenience of the public that a subway should be made, and where benefit would accrue to the companies.

Turning to the practical point of the paper, he thought that it appeared that the right use of concrete was not yet understood even by engineers. Judging from what the author said, it seemed to him that they were quite in the infancy of their knowledge as to concrete. It had been his experience to employ cement concrete on some very large buildings and on a somewhat successful scale, and he had found enormous benefit from its use. In the ordinary course of his practice he had made floors absolutely uniform, level, firm in texture, devoid of cracks and free from every kind of disadvantage which might arise from even minute cracks, and he had found that nothing could be used as satisfactorily as good Portland cement concrete. He was afraid that he should not follow the rules laid down by the author as to the gauge of the concrete. His experience was that it was exceedingly desirable under no circumstances to spare the use of water, though it should not be put on lavishly with buckets. There should certainly be a larger quantity of water than forty gallons per cubic yard. It was exceedingly desirable to make the concrete as wet as they could get it. It should be so wet that it would go down by its own weight like batter. He had found that the whole essence of getting the strength and stability was to use sufficient water. If there was sufficient water used it was impossible that there would be want of a cohesion between the successive layers.

Mr. GEORGE GREEN said that he should not like it to go forth that there was any engineering difficulty in putting a subway into any main thoroughfare of the metropolis. The great and real difficulty which seemed to be in the mind of everyone was that of finance. The members present knew that within recent years a large portion of the space between the Mansion House and the Royal Exchange had been filled with subways, practically he believed from kerb to kerb, by the Central London Railway. The whole of those subways and also the station of the company had been made without any stoppage of the traffic. If such work was possible in front of the Mansion House it was also possible in all the leading thoroughfares in London. But the construction of subways and the putting of new mains required the expenditure of enormous sums of money; it was a question of finance rather than engineering, and it remained to be seen whether the citizens of London were prepared to go to the cost which would necessarily be involved. Engineers could do the work if the public would pay the cost.

Mr. W. H. HOLTTUM said that there might be some misapprehension with regard to the references made in the paper to existing London subways. They were alluded to as being from 14 feet by 7 feet 6 inches to 8 feet by 7 feet. He was not at all familiar with such dimensions. The subways which had been made in London were generally in the clear 12 feet wide by 7 feet 6 inches high. He understood that some portion of Rosebery Avenue varied in size where it was not really in the nature of an ordinary subway. Mr. Percy Griffith said that he thought that the gas companies and the water companies would be inclined to pay something for the advantages of having a subway; but he (Mr. Holttum) believed, from his limited experience, that the companies did not regard subways so favourably, neither did they appreciate the prospect of their mains leaking too perceptibly. In 1895 he had been engaged upon the widening of Sandy's Row, in the east of London, the City of London Corporation doing the work at one end and the London County Council at the other. That was a very narrow thoroughfare, having two gas and water companies' mains laid along it. The widening was effected for a 40 feet road, with the customary 12 feet by 7 feet 6 inch subway, but the companies could not be made to bring their pipes inside the subway, and every one of the mains had to be shifted from their original positions, re-laid outside, and to be clear of, the new subway. Thus the companies did not avail themselves of the advantages of the subway; there was no rent-charge to help the cost of subway, and nothing to upset the right of the companies to excavate from time to time for purposes of repairs to the mains.

As to the construction of arched subways in concrete, he thanked the author for bringing the subject forward for consideration, and he agreed that it might be inexpensive if it proved possible to obtain suitable concrete material in situ. He did not see the necessity of forming the floor of subways in concrete, as a good firm gravel floor had the advantage of readily admitting the flanges, or socketed portions of pipes, and the body of the pipe beds well upon it.

The author showed a disconnecting or inspecting chamber within the subway in the left hand of Fig. 4. A multiplicity of chambers such as those from the houses draining thus through the side or dual subways would, unless they were kept uncommonly air-tight, admit foul gas into the subway.

He quite agreed with the author in saying, "Whatever class of subway is adopted, a point of considerable importance would be to make the best use of every portion of available space." That was a truism. He had often thought that, although the semi-arch was doubtless the strongest and most economical form, and that the passing over of the inevitable steam-roller must be considered, still he should say that instead of having an arched interior, a square form might be adopted, which would certainly allow of space being more conveniently utilised. The sooner they could get to the trough girder form top the better. He looked forward to the time when nearly the whole width of the carriage-ways of important thoroughfares would be so sub-constructed, and the re-filling of excavated material be reduced to a minimum.

The author's proposal as to the electric lighting of the subway was a magnificent and very beautiful one, and he should say that whenever the cost of it was incurred it might be well to admit that sight-seeing ratepayer already referred to in the paper, for whom the spiral steps were to be put in. He (Mr. Holttum) thought that it would be much better to keep the entire control of the subways in the hands of the owners' responsible official.

The ventilation of subways was a most important consideration. They had been ventilated in the carriage-way. The ventilator got mired up in time, after a heap of detritus had got through and on to the floor of the subway. It was too seldom anybody's business to clear it, consequently the subway became non-ventilated at the few places which were designedly placed for ventilation. He did not want the horse-road full of cast-iron surface-boxes and ventilators, but thought that a subway should be ventilated on to the footways. Nothing disagreeable would emanate from the subway, provided that there was proper inspection of the pipes, etc.

He had himself intended to speak about the very ingenious collapsible centering and the convenient removal of it, but others had already commented thereon. Of course the removal of centering could not be got on with until the concrete was properly set. He did not approve of centering being moved forward quite so quickly as some interested parties would wish.

In this connection he would ask the author if he had had any experience in building a subway in concrete where the concrete showed cracks right round it at distances of 12 feet or 15 feet apart, and whether such cracks would not be very detrimental to the strength of the structure? Still he should like very much indeed to see concrete subways. He had always had a great appreciation for good Portland cement concrete, although, from some combination of circumstances—it might be indifferent materials, or careless manipulation—many concrete structures showed those objectionable lines of fracture commonly disposed of as being due to "expansion and contraction."

Mr. PERRY F. NURSEY, referring to the question of using sea-water in connection with concrete or cement, said that some years ago he was constructing some powder magazines in brickwork and cement on the Essex coast, at a place a long way from a supply of fresh water, and there arose between himself and the contractors the question of using sea-water instead. Eventually he gave permission for sea-water to be used, and no harm whatever had come of it. The bricks were soaked in sea-water and the cement gauged with it, as was also the concrete for the floors and approaches of the magazines. That work was done some twenty-five years ago and it was still as good as ever, no deterioration having taken place to his knowledge.

Mr. J. W. BRADLEY said, that, to his mind, the cost of subways was the crux of the whole thing. Engineering difficulties, whatever they were, could always be overcome. The question of subway construction arose generally on two occasions. The first was when a new street was being formed. The second was when a street had had many pipes of all classes placed in it, and was continually being broken up for alterations and extensions to mains. In the first case—that in which Mr. Allen endeavoured to show subways should be adopted generally—the cost of subways was given by Mr. Allen at 2*l.* per lineal yard, and Mr. Allen advocated that subways should be placed in the street when the street was newly formed. Now an ordinary town of a hundred thousand inhabitants would have some three or four miles of new streets formed annually. The cost of constructing subways in those streets, even at Mr. Allen's very low price, would amount to about 12,000*l.* per annum. The present cost of repairs to streets and alterations to mains would probably not amount to more than 2000*l.* per annum. Therefore, if subways were made the town would be paying 10,000*l.* for a year because of a sentimental objection to having the streets partially and temporarily blocked up, for in such a town the matter was really more a sentimental matter than one which really detrimentally affected the formation of the streets or the comfort of those using them.

As to the second case, the one in which the streets already formed had a large number of mains in them, to construct subways to contain those mains and to take each of the pipes and place it in the subway, would involve a cost not of 2*l.* per yard, but probably 200*l.* or 300*l.* per yard in a metropolitan street of any importance. There was always one of two great obstacles in the way of the construction of subways: when they could be constructed economically their use could be so limited that, despite their economical construction, the first cost would be far too great; or else, when they might have full use made of them, the cost of taking up existing mains and placing them in subways altogether precluded the construction of such a convenience. It seemed to him that the only cases in which subways could really be constructed with economical advantage were in cases where new streets were being cut through areas cleared for purposes of public improvements. The fact that those areas were being cleared for purposes of public improvement indicated a densely-built district, and that there would be a large number of mains to lay at once, so that the full value of the subway would be immediately felt, apart from its prospective value, which time might never realise. In cases of that sort they might certainly be constructed with advantage.

With regard to the placing of pipes in subways, the telephone and telegraph companies were altogether averse to paying an annual rent for the wayleave. They would much rather pay a lump sum, even if it was somewhat excessive, and have done with it. The gas companies were also averse to laying gas mains in subways, because of the damage which might follow from an explosion resulting from the accidental ignition of an accumulated mixture of coal gas and atmospheric air.

He should like to point out one thing with reference to the composition of concrete, and that was the value of specifying the minimum size of the broken stone. The engineer might say that the broken stones had to pass through a certain mesh; but if they did not keep the dust and small stones out of the aggregate they might be having a 10 to 1 concrete instead of a 6 to 1 concrete—something which was very much poorer than was intended. His own practice was to specify that broken stone, brick, ballast, or whatever the material might be, should be of such a size as to pass a certain sized screen and be retained on one with a mesh an inch or an inch-and-a-half less.

With regard to the specification for the tensile strength of the cement, namely, 350 lb. to the square inch for seven days, in his experience 450 lb. was a very common specification, and one easily conformed to, although, of course, other points, such as specific gravity, quickness of setting, etc., had to be considered. He could quite bear out what previous speakers had said with regard to the use of the patent centreing. It was absolutely necessary that the centreing should remain in from four to six days, and he failed to see that quick-striking centreing had any special value in the construction of concrete subways.

Mr. J. W. Wilson wished to point out that Fig. 7 was a diagram of an arch which was supposed to have radiating joints. He did not see that they were radiating. He supposed that the divisions shown were intended to represent independent voussoirs, and they would be devoid by stability. He was quite sure that a great deal of the inconvenience of disturbing streets and pathways could be avoided with a little reasonable care and co-operation on the part of the companies and the authorities. He knew of a pathway which was recently tar-paved and which was pulled up again in the course of a week or two for the laying of longitudinal mains. Not long ago, also in the same district, in front of a new row of small houses the pavement was formed, and in a fortnight it was picked up again at short intervals to lay the water services from the main to each house. Such disturbances could be avoided by a little reasonable forethought, and a great deal of annoyance prevented if those matters were dealt with from the right point of view, and if more attention was paid to the question of public economy.

The President said that they had had a very inieresting discussion on the paper. As he had stated in his opening remarks the matter was one of great difficulty, and they had now heard more about those difficulties. He must again thank Mr. Allen for bringing the matter before the Society, and he still hoped that subways would become general both in old streets as well as in new ones. He knew that it would be very difficult to get them; but the work could be done, and he did not agree with some of the speakers as to its impracticability. They all knew that it was a hard matter to raise the large sums of money which would be necessary; but if the subject were approached judiciously and in the right manner they might get Parliamentary powers to compel the companies to go into the subways and pay a rental for their use. Mr. Blair mentioned the sum of 12,000*l.* as having been paid in St. Pancras for pulling up and reinstating streets for one year. Why could not the 12,000*l.* be charged as interest on capital required for subway construction? It seemed to him that there would then be a very good return for the outlay.

The PRESIDENT then stated that, owing to Mr. Allen's absence through illness, a report of the discussion would be sent to him for his reply in writing.

Mr. ALLEN wrote:—In acknowledging the vote of thanks, my first duty is to thank the President and the members for the kind way in which my paper was received. I am deeply gratified to think that the object I had in writing the paper has been achieved. That object was to put before the Society certain views which would enable a discussion to take place and lead to an interchange of opinions.

In reply to the President I would point out that it was not my intention that such subways should be thrown open for general public inspection, but that admission should only be granted to ratepayers seeking such by appointment. At the opening of the St. Helens subway on April 28, 1899, Alderman Cook suggested that certain days should be set apart on which ratepayers could inspect the subway, and the engineer, Mr. George J. C. Brown, M. Inst. C.E., said he saw no difficulty in that, but he thought they should not open it generally. I quite agree that it would be unwise to throw a subway open generally for the admission of the public.

Mr. Percy Griffith raises a financial question regarding the vaults. Estimating these approximately at 20*l.* each, and there being vaults under each causeway, they would cost therefore about 12*l.* per running yard of the street. The vaults, if let on a rental of 1*l.* per annum, or 5 per cent. on the outlay, would show a profit of 1½ per cent., presuming the money was borrowed at 3½ per cent. The number of openings referred to in my paper is for a period of one year, and the places with a population varying from 40,000 to 5000 were selected at random to substantiate my statement that both large and small towns suffered alike from the breaking up of roads.

In reply to Mr. J. Patten Barber my estimate of 2*l.* per lineal yard for each small subway, as shown on Plate II., was based on the cost of such work in my district, where the substratum is of a stony nature.

Mr. William Blair's remarks call for little comment on my part. With most of what he says I agree.

In reply to Mr. D. B. Butler I may point out that I am not prejudiced against sea-water being used for concrete work, and only referred in my paper to care being exercised in using sea-sand, more particularly owing to its being more deficient in sharpness.

Mr. W. H. Holttum has drawn my attention to the sizes I have given in my paper for the London subways. I very much regret, if I have made a misleading statement, but the sizes quoted are taken from a report of the Borough Engineer of St. Helens, who, with the Water and Gas Engineer of that Borough, visited London for the purpose of obtaining particulars of the subways referred to in my paper. I have personally had no experience in the direct construction of a subway in concrete, but have had considerable experience in the construction of concrete precipitation tanks and manholes.

I must thank Mr. J. W. Wilson for calling my attention to a very serious defect in illustrating Fig. 7, which should have been shown with radiating joints.

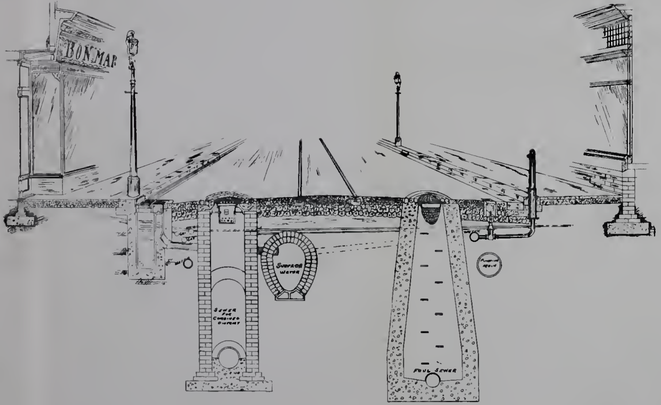

BON MAR
SURFACE WATER
SEWER FOR COMBINED SYSTEM
FOUL SEWER

Fig. 1.

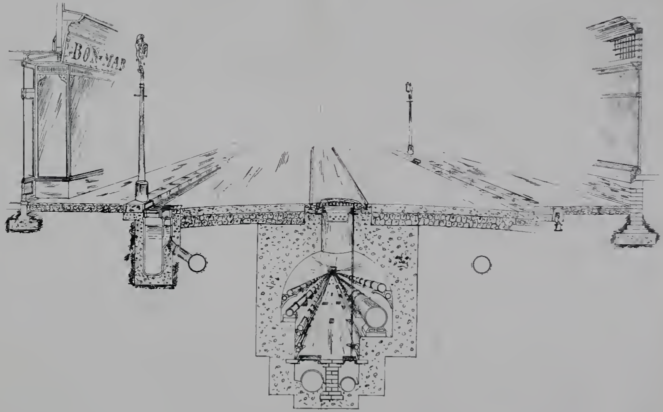

BON MAR

Fig. 2.

CONCRETE SUBWAYS FOR UNDERGROUND PIPES. BY A. T. ALLEN.—PLATE II.

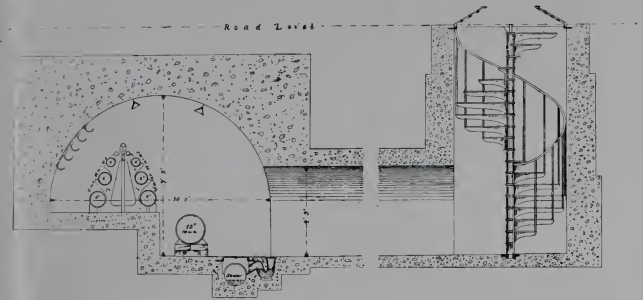


FIG. 3.

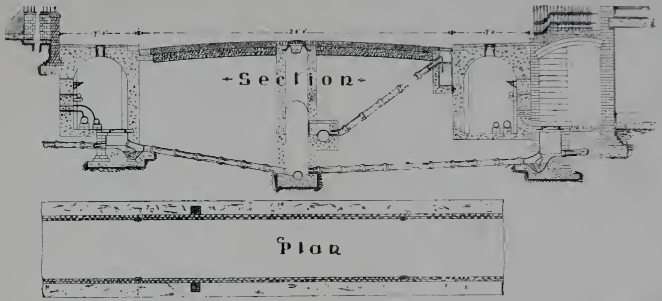


FIG. 4.

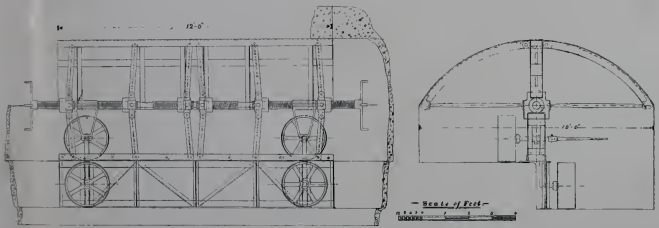


FIG. 5.

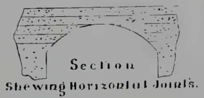


FIG. 6.

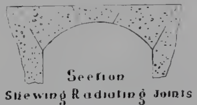


FIG. 7.

VACATION VISITS.

THE usual Vacation Visits were made during the summer and autumn of 1901. They were three in number, and the first, on June 12, was to the air-compressing station for the Shone system of sewage ejection at the Sewage Disposal Works, Erith, Kent, and the Engineering Works of Messrs. Fraser and Chalmers, which are also situate at Erith. The second visit, on July 18, was to the Staines Reservoir Works, Staines. The third visit, on September 25, was to the School of Military Engineering, Chatham.

The following are general descriptions of the several works visited.

THE ERITH AIR-COMPRESSING STATION.

The Erith Sewage Disposal Works in which the air-compressor plant is working are situate in Manor Road, Erith, at the east boundary of the district on the banks of the River Thames, and occupy about two acres of land. The gas engine air-compressors are four in number, being two sets in duplicate. The first pair produce the compressed air for working the Shone ejectors for pumping the low-level sewage. These engines were made by Messrs. Crossley Bros., and comprise two Otto gas engines and air cylinders, each to compress 158 cubic feet of free air per minute to 11 lb. per square inch. The second pair produce the compressed air for the sludge pressing and for driving the mixing machinery. The gas cylinders indicate 25 horse-power each engine, and the air cylinders are capable of delivering 250 cubic feet of 100 lb. per square inch air per hour. All four engines have automatic arrangements for throwing the air cylinders out of work when the working pressure in the receiver is reached. The second pair have this apparatus so arranged that the air cylinders can be entirely thrown out of work for any desired period. In addition to the foregoing, small air pumps are fixed in each ejector chamber in order to pump out the condense water from time to time as it accumulates in the chambers. Dowson gas is used for the gas engines, and is produced by the plant erected at the works by Messrs. Paisley, Welsh and Co.

The air main is laid at a depth of about 4 feet along the Manor Road, High Street, West Street, Lower Road, and Lower

Abbey Road, to the several automatic ejectors situate in those roads, the last station being about three miles from the works. Following are particulars of station plant:—

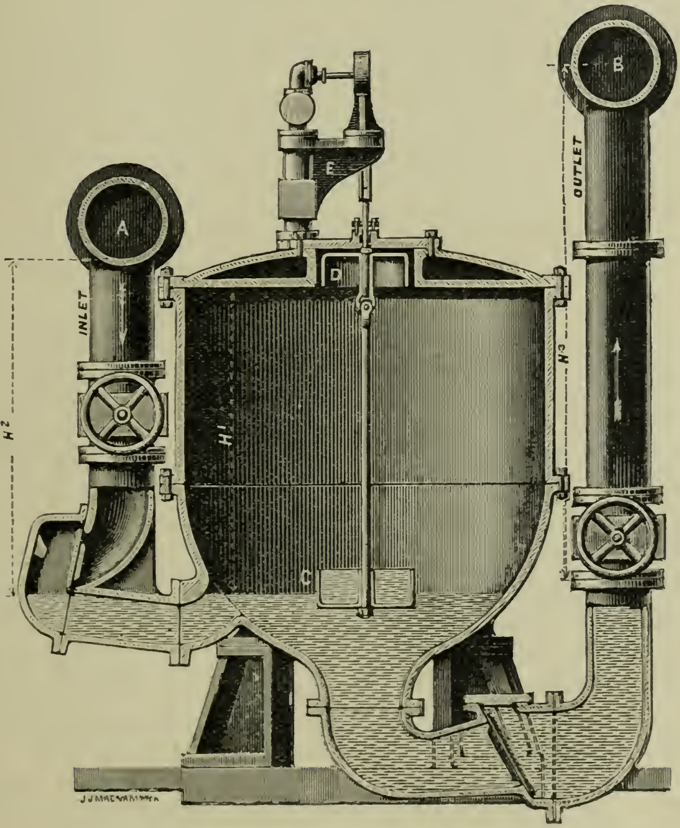
Station.	Name of Station.	No. of Ejectors.	Discharging Capacity of each Ejector in Gallons per Minute.	Size of Air Supply.	Size of Air Exhaust Pipe.
				inches	inches
No. 1	Appold Street	2	300	2½	2½
„ 2	High Street	2	200	2	2
„ 3	Lower Road	2	150	2	2
„ 4	Station Road, Belvedere . .	2	150	2	2
„ 5	Lower Abbey Road . . .	2	50	2	2

The compressed air is delivered to the ejector stations through 4600 feet run of 4-inch cast-iron socket pipe, jointed with yarn and lead, and 10,900 feet run of 3-inch similar pipe. All the pipes were tested to a pressure of 40 lb. per square inch. The fall in pressure in one hour does not exceed 5 lb. The compressed-air pipe is provided with stop valves close to each of the automatic valves, so that each of the ejectors can be repaired independently of the working of the others. Syphons for drawing off water are constructed at several points in the air main.

THE SHONE EJECTOR SYSTEM.

The Shone system of sewerage may be briefly described as a system of distributed stations for the lifting of sewage, worked from one central station by means of compressed air, whereby the whole drainage area is divided into a number of compact districts, each with its separate outfall and discharging station, the discharge from all the stations converging into one common main leading to the ultimate common outfall. The system is applicable wherever the sewage of a town or district requires to be lifted. Annexed is a sectional view of Shone's pneumatic ejector.

The motive power employed is compressed air, and the action of the apparatus is as follows:—The sewage gravitates from the sewers through the inlet pipe A into the ejector, and gradually rises therein until it reaches the underside of the bell D. The air at atmospheric pressure inside this bell is then enclosed, and the sewage, continuing to rise outside and above the rim of the bell, compresses the enclosed air sufficiently to lift the bell, spindle, etc., which opens the compressed air admission valve E. The compressed air thus automatically admitted into the ejector presses on the surface of the sewage, driving the whole of the contents before it through the bell-mouthed opening at the bottom, and through the outlet pipe B into the sewage rising main or high-level gravitating sewer as the case may be. The sewage can only escape from the ejector by the outlet pipe, as the instant the air pressure is admitted on to the surface of the fluid the valve on the inlet pipe A falls on its seat and prevents the fluid escaping in that direction. The fluid passes out of the ejector until its level therein reaches the cup C, and, still continuing to lower, leaves the cup full until the weight of the liquid in the portion of cup thus exposed and unsupported by the surrounding water is sufficient to pull down the bell and spindle, thereby reversing the compressed air admission valve, which first cuts off the supply of compressed air to the ejector and then allows the air within



the ejector to exhaust down to atmospheric pressure. The outlet valve then falls on its seat, retaining the liquid in the sewage rising main, and the sewage flows into the ejector through the inlet once more, driving the free air before it, through the air valve, as the sewage rises; and so the action goes on as long as there is sewage to flow. The positions of the cup-and-bell floats are so adjusted that the compressed air is not admitted to the ejector until it is full of sewage, and the air is not allowed to exhaust until the ejector is emptied down to the discharge level. The compressed air for actuating the ejector is produced at a central station, and is conveyed in iron pipes laid under the streets to the several ejector stations, as already explained. The Shone ejectors at Erith were supplied, and the air mains laid, by Messrs. Hughes and Lancaster.

Messrs. Fraser and Chalmers' Works.

These works have been in operation for about ten years, and are well equipped with modern tools and appliances. The manufactures carried on are gold and silver mining machinery, hoisting and pumping engines, Riedler patent mechanically controlled valves for pumps and air compressors. The iron foundry is 220 feet long by 150 feet wide, and has four bays; the two centre ones are each of 50 feet span, and the sides 25 feet span. The centre bays are served with three travelling cranes of 5, 15, and 25 tons capacity, also four hydraulic cranes of three and five tons capacity. Besides the three large core ovens of 4000 cubic feet capacity each, there is installed the Piflin portable stove, by which the largest moulds are dried on the floor at less cost than by the old method of fixed core ovens.

The boiler shop measures 220 feet by 120 feet, and consists of three bays. The centre bay is of 60 feet span, and is served with a 25-ton power-driven travelling crane. The side bays contain shears, punching and planing machines, and are served with jib cranes.

The wood-working shop is a two-storey building, 120 feet by 60 feet, and has a lumber shed adjoining, 220 feet long. These shops contain the most modern wood-working tools suitable for getting out stamp mill frames and other work required in stamp mill practice. The upper floor is the pattern shop, which is also supplied with suitable wood-working machines. The blacksmith's shop is 140 feet by 60 feet, and is equipped with four steam hammers and band and circular saws. One end of this building is fitted up as a polishing shop, where all the work is polished before being shipped.

The machine and fitting shop is 440 feet long by 110 feet wide. One end, 180 feet long, has a centre bay 50 feet wide, served with two travelling cranes of 20 tons capacity, 34 feet high above the floor. Side bays, 25 feet wide, are served with hand travelling cranes of 5 tons capacity. The centre part of the building, 200 feet long, contains four bays. This part of the shop is occupied by lathes, planers, and other iron working tools, and most of the machining is done here, the hand fitting being done in the side bays in the part first referred to. The last 60 feet is an erecting shop, which is served with an electric crane of 25 tons capacity, and an auxiliary 5-ton hoist on the same trolley as the main hoist. In this shop is a pit 80 feet long by 20 feet wide and 8 feet deep, covered with a removable floor, so that in erecting vertical engines there is a vertical height under the crane of 45 feet.

The works are connected by rail with the South-Eastern Railway, and cars can be loaded direct from the machine shop cranes. Machinery can also be shipped by barge to the London Docks, the works having wharf facilities and a loading crane that will handle any machinery that is shipped that way.

The Riedler Pump.

The principal feature of the Riedler Pump, manufactured by Messrs. Fraser & Chalmers, is its mechanically-operated valve, which is circular in form, and is opened automatically at the beginning of the plunger stroke, and closed mechanically and positively just at the end of the stroke. The advantages of this pump are that the valve-opening is large, and there is no throttling of the water. The positive closing of the valve prevents all slip of water, and hammering of valves under heavy heads, and so allows of very high piston speed. High piston speed means economy of steam, and large capacity for comparatively small pumps, also maintenance of continuous flow in the discharge pipe. Economy of steam and absence of slip results in great efficiency. In one test 126,000,000 foot lb. per 1000 lb. dry steam was the result; in another case, on a larger engine, 159,000,000 foot lb. As an instance of speed, one small pump of 100 gallons per minute against a head of 1650 feet, through 5½ miles of 3½-inch pipe (equal to 935 lb. per square inch), has been run up to 200 revolutions per minute. High piston speed allows of running the pump in emergencies far above the normal speed without injury, so that sudden increase in water in mining operations can be met.

Staines Reservoirs Works.

These works, which are the joint property of the New River, West Middlesex, and Grand Junction Water Companies, are near Staines. The intake from the Thames is situated in Buckinghamshire on the left bank of the river, about 300 yards above Bell Weir. At this point sluices and a sluice-house are constructed, the intake being protected by screens to prevent leaves and other floating matter from entering the conduit. The first length of the conduit, for about 350 yards, is covered, as required by the Act of Parliament, and, running from the intake in a north-easterly direction, is carried in two steel syphons under the Colnebrook, after passing which it becomes an open conduit, the sides and bottom being formed of Portland cement concrete made in the proportion of about 5½ to 1. The conduit passes under the Great-Western and London and South-Western Railways in double tunnel, and under the Wyrardisbury River through steel syphons, crosses Staines Moor, is syphoned under the River Colne, and runs to the pumping station, situated near the Billet Bridge which carries the London Road over the River Ash.

The pumping machinery will consist of five triple-expansion surface-condensing Worthington pumping-engines (one being a spare engine), each capable of delivering 16 million gallons of water daily into the reservoirs. Steam will be provided by six Babcock and Wilcox boilers (one spare), the working pressure being 150 lb. per square inch. The water will be delivered into the reservoirs through two riveted steel mains, each 6 feet 4 inches diameter, joining into a steel pipe 7 feet 10½ inches internal diameter near the reservoir, from which branch pipes of the same diameter will be taken down through tunnels constructed in the clay, and connected to a water-tower near the corner of each reservoir, where the western and central embankments join. The tunnels and water towers are massive constructions of Portland cement concrete, the former lined, and the latter faced with blue bricks.

The stand-pipes for discharging water from the reservoirs will be of cast-iron, 5 feet internal diameter, having 48-inch and 36-inch sluice-valves, with bell-mouth bends fitted to them, to enable the water to be drawn off at any desired level. These valves will be worked from a platform at the top of each of the water-towers, the gearing being enclosed in a suitable building. From the bottom of the stand-pipe of each reservoir a cast-iron pipe 4 feet diameter will convey the water through the tunnel and across the New Stanwell Road to a basin 50 feet diameter, in which a weir will be constructed for the purpose of aeration, and over which the water will be delivered into the conduit, which will rejoin the main conduit a little to the east of the pumping-station. Proper sluices will be provided for regulating the supply into and from the reservoirs.

The two reservoirs are about 1¼ mile long by five-eighths of a mile wide at their northern end, and nearly a mile wide at their southern end. The embankments vary in height from 21 feet to 39 feet, and are formed of material excavated from the interior of the reservoirs, the excavation just balancing the banks to prevent the expense of running material to spoil. The slopes of the embankments are three to one inside, and two to one outside the reservoirs. In the centre of each bank a puddle-wall is constructed 6 feet thick at the top, 7 feet at the ground level, and tapering down to 4 feet, where it joins the London clay, into which it is securely toothed. This construction, for which this part of the Thames Valley is favourably adapted, will make the reservoirs perfectly water-tight. The inside slopes of the reservoirs are lined with concrete 5 in. thick for a vertical depth of 15 feet, so as to resist any wave action which may take place in so large a sheet of water. The average depth of the water in the reservoirs is about 30 feet, and their content is 3300 million gallons. The aqueduct and reservoirs will be guarded on all sides by unclimbable wrought-iron fencing, and the embankments will be sown with grass.

After leaving the pumping station, the conduit is reduced in section, and runs through the Billet Bridge by the side of Shortwood Common, under the London and South-Western Railway, and across the fields, passes under the Staines and Kingston Road, the line of which it generally follows until it arrives at Sunbury Cross. From this point the aqueduct runs in a north-easterly direction, along the north side of the East London Water-works at Hanworth, after which it bends to the south, passes under the Thames Valley Branch of the London and South-Western Railway, and is finally joined to a reservoir of about 30 million gallons capacity, which is constructed to the east of Kempton Park. The New River Company will take its water from the aqueduct between the East London Water-works and the Thames Valley Line. The West Middlesex and Grand Junction Companies will receive their proportion of the water from the Kempton Park reservoir just alluded to. Proper measuring apparatus of special construction will be provided on the aqueduct leading from the Thames to the pumping station, on the smaller aqueduct from Billet Bridge to Hampton, and at the outlet to each of the companies. Venturi meters will be fitted in the 7 feet 10½ inch pumping mains leading to the reservoir and in the 48-inch mains leading from the reservoir. Automatic records of the water passing down the aqueducts, of the level of the water in the aqueducts, and of the water passing through the several Venturi and other gauges, will be kept, and in most cases will be repeated in the engine-house. The capital provided under the Staines Reservoirs Act, 1896 and 1898, is 1,250,000*l.*

Progress of Works.

At the date of the visit great progress had been made with the lower portions of the aqueduct and the Hampton distributing reservoir. At the intake at Bell weir, the sluices were practically finished, and so was the conduit along which the water flows by gravitation from the intake to the pumping station at the reservoirs. The boiler-house and the engine-house were complete, but the boilers were not yet in place; the pumping engines were, however, in course of erection. Most of the piping between the pumps and the reservoirs was also laid, and the aqueduct from Staines to Hampton had been formed. The two reservoirs, with their total combined storage capacity of 3300 million gallons, were both finished as regards their embankments, which measure about four and a-half miles round. The more northerly of the two was rapidly nearing completion, little remained to be done beyond putting in the concrete facing, to resist wave-action on the higher portions of the slopes, of which about three-quarters were already in place. It was expected that this reservoir would be ready for use in the course of the year. The southern reservoir was in a less advanced condition, but would probably be finished in 1902. When this has been done, the three companies concerned—the West Middlesex, the New River, and the Grand Junction—will have an additional supply of 35 million gallons a day. When the flow of the river at Bell weir exceeds 265 million gallons a day they may abstract any surplus up to 100 millions, of which 35 million gallons may be run direct to the filter beds at Hampton, and the residue pumped into the reservoirs. If the flow at Bell weir is less than the minimum specified, nothing may be taken from the Thames there, but the companies have the water stored in the reservoirs to fall back on. It follows, therefore, that London generally—for by means of connecting-mains other companies besides those directly interested will be able to share in the new supply in case of emergency—will derive from the new scheme at Staines an increased supply of 35 million gallons a day, taken direct from the river if the Thames is full, and, if it is low, from the reservoirs, which alone will be able to yield that amount for over three months.

The works were designed, and were being carried out for the Joint Committee, by Messrs. Walter Hunter and Reginald E. Middleton, MM. Inst. C.E., of Westminster, the contract being entrusted to Messrs. John Aird and Sons, of Lambeth. Messrs. James Simpson and Co., London, were constructing the pumping engines; Messrs. Thomas Piggott and Co., Birmingham, the steel pipes; and Mr. G. Kent the gauges.

THE SCHOOL OF MILITARY ENGINEERING, CHATHAM.

The third and last visit was made to the School of Military Engineering at Chatham, by permission of the Commandant, General Sir Thomas Fraser, K.C.B. Upon arriving at the Royal Engineer Barracks, Chatham, the visitors were received by Col. Purcell, R.E., and Major Macdonogh, R.E., Brigade Major, in the unavoidable absence of the Commandant, and were entertained at luncheon at the Royal Engineers' mess, the string band of the corps performing during luncheon.

After luncheon the tour of inspection commenced under the personal superintendence of the officers lastly referred to. The party first visited the Royal Engineer Institute, where, under the guidance of Major Winn, they were shown the survey, construction, fortification, and photographic and lithographic schools. They then proceeded to the Royal Engineer Park, where, in the Penetration ground, they witnessed a series of experiments illustrating the penetrative power of the Lee-Metford rifle at short range—about 40 yards. The first target tried was composed of 24 inches of hard wood, the maximum penetration of which is 24 inches. The target, however, was not penetrated. The service-charge was in all cases used. The next target attacked was of soft wood, the maximum penetration of which is 42 inches. The actual penetration was from 27 inches to 30 inches. Targets of coarse shingle and road metal were afterwards fired at, the maximum penetration being 3 inches and 6 inches respectively, but both remained proof against the projectiles. A sand-bag loophole was then attacked but remained proof. An earth parapet having a maximum penetration of 22 inches was then fired at, but remained proof. Iron and steel targets were then attacked by the Lee-Metford. The first was a target of wrought-iron plate half an inch thick, which resisted all attempts to penetrate it. A $\frac{3}{8}$-inch mild steel plate, followed with a theoretical maximum penetration of its own thickness, the plate being penetrated. Next came a $\frac{3}{16}$-inch hard steel plate having a maximum penetration of its own thickness, but which remained proof against the projectiles.

The party then proceeded to the bridging ground in the new ravelin, where Capt. Kemp and Capt. Singer took charge, and explained the construction and uses of four different types of military bridges. The first was an ordinary timber suspension bridge, one of the cables of which was a wire rope, whilst the other was made up of telegraph wires. It was an example of bridge-building over a river or a ravine with such materials as could be obtained at a pinch, and it occupied only three working days in construction by men who had but recently joined. The second was a suspension bridge with one central pier and two spans of about 90 feet each. The third was a small timber cantilever road bridge, with a narrow roadway. The fourth was an ingenious Indian foot-bridge, known as a "jhula," formed of three ropes with light lashings at intervals, one rope forming the footway and the other two the hand-rails, the transverse section indicating the letter V.

The visitors then proceeded to the Field Work Ground at Darland, where, under the direction of Capt. Matheson, R.E., and Lieut. Thompson, R.E., they witnessed some highly interesting demolition experiments. In the first of these a length of 72-lb. iron double-headed rail, keyed in a cast-iron chair, was attacked with a charge of 8 oz. of gun-cotton, to illustrate the method of cutting a line of railway. The visitors having entered into a splinter-proof shelter, the charge was fired, and the explosion cut the rail clean through and broke up the chair. The next experiments were illustrative of the demolition of a bridge by destroying the supports. In the first instance a 12-inch square timber pile, set up vertically in the ground, and roughly rounded at one point, was encircled at that point with a necklace of gun-cotton discs, weighing in all 2⅓ lb. On the explosion of the charge the pile was cut clean through horizontally. Two similar piles, one with 6 oz. of gun-cotton, and the other with 6 oz. of dynamite inserted in each case in an auger-hole, were then attacked. In the case of the gun-cotton the pile was greatly shattered, whilst in the case of the dynamite the pile was demolished. A bag containing 50 lb. of gunpowder, tamped with four bags of sand, was then lodged at the foot of a heavy earthwork and timber stockade. Upon the charge being fired, a clean breach was made in the stockade.

The final experiment was made with a fougasse, or rough earth-mortar. This consists of an excavation in the soil made at a slight angle with the surface, the mouth of the excavation opening towards an advancing enemy. A charge of 30 lb. of gunpowder was placed in the bottom of the pit, which was then filled up to the mouth with flints. On the mine being fired the flint stones were projected forward into the air in a whizzing shower, which would inevitably disable as well as demoralise an advancing foe. At the conclusion of the experiments the party returned to the Royal Engineers' Mess, and were entertained at 5 o'clock tea, subsequently returning to London after a most interesting and instructive visit.

October 7th, 1901.

CHARLES MASON, President, in the Chair.

PRELIMINARY INVESTIGATIONS FOR WATER SUPPLY.*

By Sydney A. Hollis.

Before proceeding to consider the general subject of his paper, the author may premise that Cape Town is well supplied with water from Table Mountain, which overlooks the town. Water is stored there by means of a large dam 123 feet in height and containing 240,000,000 gallons when full. It has been found necessary, however, to build a second dam, which is now in course of construction, immediately above the existing one, to supply the increasing population of Cape Town. The suburbs of Cape Town, which are independent townships, have separate water supplies, which, owing to expansion and increase of population of late years, will shortly be obliged to look further afield for their source of supply. It was on the preliminary investigations for the supply of certain of these townships that the author was engaged during a period of six months at Steenbrass River, which is situated about 40 miles from Cape Town, amidst the Hottentot Holland Mountains of the Cape Peninsula.

A record of the amount of rainfall in England since 1677 is in the possession of the Rainfall Organisation. These records facilitate the work of the hydraulic engineer, inasmuch as one of the primary steps he has to take, when consulted as to the best method of giving a constant supply of water by means of storage, is to ascertain the amount of rainwater available. A near approximation can only be secured when records have been kept during a number of years, and by taking the lowest recorded amount for one year a safe basis is obtained. This allows the engineer in Great Britain to arrive at a conclusion very quickly and with perfect safety. It is otherwise when dealing with the same subject in countries where no records have been kept. In addition to this, in countries such as South Africa, the following difficulties occur:—

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* A Society's Premium was awarded to the author for this paper.

I. A very large difference in the amount which falls in summer and in winter.

II. The difference from year to year in the total rainfall.

III. The different way in which the aggregate yearly fall is made up.

IV. The vastly different amount of rainfall in all parts of the country.

It is possible for an amount of rain to fall in two or three days, which on other occasions would be spread over twenty or thirty days. It will thus be seen that, in dealing with tropical or sub-tropical countries, a large margin must be allowed, or, in other words, a far greater allowance must be made for extremes in the way of an excessive drought during a long period, or an excessive rainfall in a short period. The rainfall of Cape Town is stated to be from 30 inches to 40 inches per annum. Although this may be satisfactory to the Meteorological Commission, it gives an entirely erroneous idea of the amount that actually falls in the Cape Peninsula. As much as 20 inches has fallen in one month on Table Mountain, and on one occasion 9 inches was recorded in sixty hours. Quite double the recorded amount for Cape Town is found to fall on Table Mountain.

The following extracts from the 'Cape Times' of September 2, 1899, show what remarkable fluctuations occur in the Cape Peninsula. The different townships referred to are within a dozen miles of Cape Town.

"During twenty-two days of the past month the rainfall in the Peninsula amounted to 17·99 inches, an amount which has only once been surpassed during the last twenty-three years, the occasion being in 1888, when 19·68 inches fell. The rainfall for eight months of the year has been 37·44 inches as compared with 42·63 inches for the corresponding period of 1898."

"The rainfall at Claremont during the month of August reached an unprecedented total of 26·91 inches. The highest amount recorded in any previous month during the last thirteen years was in June 1888, 22·70."

"At Sherwood, Kenilworth (near the railway station), the total fall from 1st January last to 31st July was 21·02 inches, being 17·08 inches less than the same period for last year, and 7·07 inches less than the mean fall for the same period during the previous ten years. During August there fell 21·05 inches on twenty-six days; this being the heaviest rainfall recorded here in any one month since 1st January, 1889, when the register was first begun. The highest previous fall was 16·45 inches in June, 1892."

"The total now for the eight months of the present year stands at 42·07 inches, as against 50·88 inches during the same period of 1892, and as against 34·43 inches, the mean annual fall for the same period during the previous ten years. That we are never without winter rains is true: but the quantity is very variable, as may be seen by the fact that in 1896 we registered here only 32·30 inches, and in 1892, 63·08 inches, or nearly double that quantity."

These enormous fluctuations show that it is absolutely necessary to institute a system of gaugings of rainfall and of the main stream. Although the results of these investigations cannot be deemed accurate unless carried on for a considerable period, a very fair estimate can be arrived at in the course of six months if the winter or rainy season be included in this period. Of course where a district suffers from long droughts, such as occur in Australia and many parts of South Africa, the only reliable method of obtaining a constant supply of water is from a river of which the normal summer flow is such that, with the aid of storage by means of a dam, the requisite amount of water can be conserved. In the case of a dam being built to conserve the water of a stream which is subject to very large fluctuations in winter and summer, the method to be followed in order to arrive at an estimate of the amount of water available for use (and a very fair estimate can be obtained in one season) is by means of gauging the main or tributary streams, the rainfall and evaporation.

The author will illustrate this by the following account of investigations he was engaged in during a period of six months at Steenbrass River, Cape Colony, the intention being to eventually construct a dam across the valley. The watershed consists of a valley five miles long by about one mile wide, surrounded by hills or kopjes, rising to a height of 4000 feet above mean sea-level, the lowest part of the valley being 1000 feet above mean sea-level. The total watershed area is 24 square miles. The main stream is fed by three small tributary streams rising in the surrounding hills. The total flow of water in summer (about six months) is from 250,000 to 500,000 gallons per day of 24 hours. In the winter this flow occasionally rises to over 300,000,000 gallons per 24 hours.

The gauge for the largest of the tributary streams consisted of the ordinary V notch gauge built in concrete. For the summer flow in the main stream, a 4-V notch gauge was erected. For the winter flow a square notch gauge, measuring 60 feet across the notch, was erected. The gauge itself, Fig. 1, consisted of 9-inch by 3-inch deals bolted together. Short iron ties were fixed to the front and bottom, the whole being bedded in concrete. From each end of the gauge, concrete walls were carried through to the banks on either side. Considerable difficulty was experienced during the course of erection, as the rain set in before completion and before the concrete had completely hardened. Some damage was caused by the first flood, but this was repaired and a complete record of gaugings was taken.

The method adopted for reading the height of water was as follows (see Fig. 2). A 1-in. galvanised iron pipe was built in the concrete wall at one end of the gauge at a slightly lower level than the knife-edge of the gauge. To the end of this pipe, on the side opposite the water, a glass tube was fixed vertically, and a board marked in feet and inches was placed against the tube, zero being on the level of the knife-edge of the weir. The actual height of the water above the edge of the gauge could be seen in the glass tube and read off the marked board. This allowed some very accurate gaugings to be taken, and was especially convenient at night time. At one time there was a fall of over 9 inches of rain in a little under two days. This caused a rise in the stream from 2,000,000 gallons per 24 hours to over 300,000,000 gallons. The large flow, however, only lasted a few hours, and the stream fell rapidly as soon as the rain ceased.

A record of rainfall was kept from six gauges placed in different parts of the watershed. During the summer months the rain gauges were read after every rainfall. In the winter once every week, with the exception of one gauge placed conveniently near the camp. This gauge was read several times in the hour during heavy showers, and in ordinary rains every three hours during the day and every six hours during the night. Readings of the height of the water over the gauge weir were taken in conjunction with the rain gauge.

It will thus be seen that the advantage of both gauging the stream and taking measurements of the rainfall allows for a comparison between the absolute amount of rainfall and the amount of rainfall flowing off the watershed that is naturally available for storage. As there are frequently underground currents that carry off a large proportion of the rain that falls, it is of the greatest importance that a knowledge of this should be arrived at before deciding on the size of dam to be constructed. During an exceptionally dry year it would have been possible for only 150,000,000 gallons to be available from the stream during nine months of the twelve, and thus, if it were necessary to supply 2,000,000 gallons per diem during this time, a storage of 400,000,000 gallons would be necessary.

Readings from thermometers (maximum and minimum, wet and dry) were taken every morning, and evaporation gaugings were taken during the whole period of six months. The temperature in summer months varied from 80° F. to 104° F. in the shade, and in the winter months from 31° F. to 50° F. in the shade. When the dry south-east wind blows in the summer the evaporation is frequently 0·20 inch in the twenty-four hours. This evaporation on a surface of water of 40 acres would represent a loss of 180,000 gallons in the twenty-four hours.

In cases similar to the foregoing an approximate gauging can be obtained by taking a section across the stream and by obtaining the rate of flow of the stream by means of a properly adjusted float. For a preliminary report this method would be found quite accurate enough in places where there are considerable fluctuations from year to year. The more accurate method should, however, be adopted before finally deciding on the size of dam to be constructed. If these records are obtained from the commencement and carried on continuously, no difficulty will be found in giving an opinion as to the advisability of increasing the height of the dam or of building a second dam at a future date. In fact, the longer these records are kept the easier it is to give advice when called upon, and to utilise to the utmost the watershed area.

In conclusion, the author would draw attention to what is becoming more generally recognised by engineers—viz. the advisability of not economising too much in the expense of obtaining preliminary information before advising upon a scheme of any magnitude. This has to some extent been recognised in the colonies during the past few years. Many thousands of pounds will eventually be saved by the foresight of those who insist in the first instance on the investigations being carried out with a due regard to the comfort and remuneration of the investigators. In former years it was the custom to have surveys made in a hurried and cursory manner, those engaged on them having to "rough it" in the true sense of the word. The result was that the information obtained was frequently unreliable. This is rarely the case now, as this policy has shown itself to be the most expensive in the end.

DISCUSSION.

The PRESIDENT said that the Society was very much indebted to Mr. Hollis for his interesting paper, which provided many points for discussion.

The difficulty of obtaining rainfall statistics in a country like South Africa appeared to be great. The author said that the meteorological authorities gave the rainfall at Cape Town as from 30 inches to 40 inches; and then in another case he said that the rainfall in one month was nearly 27 inches. That led one to think that the authorities ought to supplement their statistics with monthly results. The water supply of Cape Town and its suburbs reminded him very much of the case of London, where they had several water companies for practically one area of supply. Perhaps Mr. Hollis would tell them how the method worked in Cape Town. In London there had been an agitation for several years to get the whole water supply under one government, which, if effected, would no doubt be to the benefit of the public and the consumer. He concluded by moving a vote of thanks to Mr. Hollis for his paper.

The vote of thanks was carried unanimously.

Mr. G. MAXWELL LAWFORD said that Mr. Hollis stated in his paper that by taking the lowest recorded amount of rainfall for one year a safe basis was obtained. He (Mr. Lawford) thought there must be a slight mistake there, for the invariable custom among engineers in this country was to take the mean of three dry years, which usually, as would be observed in rainfall returns, occurred in a cycle of from seven to ten years. This country had just completed such a cycle, and the returns would show that the last three years had had an unusually low rainfall, and we should probably have an increasing rainfall during the next six or seven years. Of course the study of rainfall was very important to water engineers, not only in this country, but in the tropical countries to which the paper alluded. He fully realised the difficulty which was met with in those countries where there was neither Ordnance maps nor rain gauges.

He was very pleased to find in Mr. Hollis's paper an illustration and a description of the piezometer tube for gauging water. That was an invention which was used very largely in America, but, apparently, it had not found favour in this country. The Society of Engineers was certainly to be congratulated on being the first society which, to his knowledge, had had that useful recording instrument illustrated in their transactions.

Mr. HILTON JOHNSON said that he observed in Mr. Hollis's paper a quotation from *The Cape Times* of September 2nd, 1899. He had been wondering whether the statistics were available from any other source.

Mr. J. FREEBAIRN STOW said that it had given him very great pleasure, as one who had lived for some years in South Africa, to listen to the very interesting paper which had been read by Mr. Hollis. He did not think that that paper wanted any criticism from a man who was accustomed to colonial engineering practice. The most interesting point of the whole paper seemed to him to be the concluding paragraph, in which the author drew attention to what had now become generally recognised by engineers, namely, the advisability of not economising too much in the expense of obtaining preliminary information before advising upon a scheme of any magnitude. Mr. Hollis had stated that that point was properly recognised in the colonies at the present time. It was very easy to understand why it had been recognised there, for at the head of the Public Works Department in Ceylon and the Irrigation Department of Ceylon, and in the Public Works Department of Cape Colony the head of the Department was a qualified civil engineer, a man of professional training and sound practical experience, who knew what the value of preliminary investigation was. In England the purse strings of all engineering schemes of any magnitude were in the hands of public authorities; and the members of those bodies, though they might be and were, as a rule, well meaning men, they were afraid, especially if it was near the time of an election, to vote money for preliminary investigations for fear that they should lose their seats through putting, perhaps, a farthing on the rates.

It seemed to him that Mr. Hollis's remarks applied to schemes of sewerage and sewage disposal, as well as those of irrigation. He (Mr. Stow) knew a district within fifteen miles of London in which the district council adopted a scheme of sewerage and sewage disposal, for which the engineer's estimate was 23,000*l.* The contracts amounted to 25,000*l.*, and the scheme up to the present time had cost 57,000*l.*, and the Council were still spending money. The reason of that state of things was that the district council had put off the carrying out of a scheme; and the Local Government Board, which was usually very slow to move, suddenly developed a fit of energy and required them to adopt some scheme, and the authority adopted one, but had no time to make preliminary investigations. The subsoil in which the sewers were laid was presumed to be composed of clay or a perfectly dry formation, but when the ground was opened the subsoil was found to be waterlogged, and at the present time the whole of the sewers were practically leaking. Two years passed, and a very eminent engineer, a past president of the Society of Engineers, was called in to design the outfall works, but his efforts were in vain, for although he presented to the Council a splendid piece of engineering construction, with every gallon of sewage which was delivered on to the bacteria beds the Council was pumping four gallons of subsoil water. In England, wherever failures did occur, in nine cases out of ten, be it water supply or sewage disposal schemes, they were ruined in consequence of the penny-wise and pound-foolish conduct of district councils, in not providing their engineers with funds with which to make the necessary preliminary investigations. If preliminary investigations had been made in the case of which he had spoken, and the nature of the subsoil ascertained, proper provision would have been made for cast-iron pipes and iron manholes, and the Council would have been probably 10,000*l.* better off than they were to-day. They would not have had to spend more than 300*l.* or 400*l.* for the preliminary investigations. He was only giving this instance as a typical illustration. The scheme to which he had referred was perhaps the worst scheme in England for leakage, and very grave errors had been made. No doubt the fault lay in the want of preliminary investigations. As to what Mr. Hollis had said about "roughing it," nobody knew better than he (Mr. Stow) knew what it was to rough it, not only in South Africa but in South America. In the case of South Africa the Government were very anxious to provide the engineer with every luxury that they possibly could.

He hoped that Mr. Hollis's remarks in concluding the paper would be brought to the notice not only of engineers, but of those public bodies which held the purse strings of municipal life, because the poor engineer was always blamed.

Mr. Joseph Price said that he understood that the piezometer or head-measuring tube was placed somewhere in the immediate neighbourhood of the edge of the weir. It seemed to him that the extent to which the tube passed into the water above the weir might influence the height of the reading. The text-books told them that in reading weirs they were to measure the height to or from still water. It was sometimes difficult to make up one's mind as to where the still water really was. Many people seemed to fancy that the measuring point for the overflow of a weir was vertical from the knife edge. Of course a measurement taken at that edge was very much less than it would be at the point of still water. If the piezometer tube only just reached to the inside of the weir, the depth would be practically the vertical column from the edge of the weir to the surface of the water at the overflow, and therefore less than the true height to still water. But even supposing that to be the case, there was no doubt that it was quite possible to have a table prepared, which would, of course, be something different from the table in the text-books, for he took it that the action of the overflow from the weir resembled very much, and was practically an approach to the Vena-Contracta which occurred when water was flowing through an orifice, and which was imitated in a great many measuring instruments and injectors of that class. He did not understand the description of the notch, as a 4-V notch.

In Cape Colony very variable readings of the rainfall could be obtained. He thought that we had precisely the same thing in this country. In one place they had boasted in certain years of a rainfall of about 260 inches. That was right up in the middle of the mountains of Cumberland. During one year he believed that it reached 263 inches without there being a continuous deluge. That was the district which, of course, should have supplied Manchester; but did not seem to have done so sufficiently recently, according to report.

Another interesting point in the paper was the amount of evaporation described. He had recently had before him the case of a well in South America, as to which he had come to the rather strange conclusion that the water was running away out of the well, from a lower stratum into an upper stratum. It was held that if that happened and continued it would mean saturation of the surrounding strata. The level of that stratum was not very high above the level of the Atlantic, and still the well had practically sprung a leak, and sprung that leak outwards. There was a parallel to this in the fact that in the Argentine Republic there were more than one river of considerable dimensions coming from the Andes which became absolutely lost. The question was where the water went to, and the only explanation which seemed to be available was, evaporation. The levels were such, that if the water flowed out through the porous beds below the surface into the sea it would have practically to flow up hill. The position seemed anomalous, but a parallel existed in the case of the Dead Sea, which was fed by the Jordan, and was very much below the level of the Mediterranean. He was not sure whether the Caspian was not similarly below sea level. All those waters must therefore be evaporated.

Mr. J. W. Wilson said that, having recently returned from the Lake District, he felt an interest in the rainfall question.

He thought that the last speaker must be mistaken when he spoke of 263 inches of rainfall in the Lake District. Seathwaite, in Cumberland, was always pointed out as having the great rainfall of 150 inches; Styhead Pass, in the same district, had perhaps rather more than that; and Dr. Mills told him that Snowdon had 180 inches. The rainfall alluded to by Mr. Price must have been very exceptional if it reached as much as 263 inches.

Mr. PRICE, replying to the last speaker, said that the place where the large abnormal rainfall of which he had spoken had occurred was Styhead. The occurrence must have been twenty-five years ago. It was an exceptional rainfall.*

Mr. E. WYNTER WAGSTAFF, alluding to the question of preliminary investigation, said that in India it had been the custom of the Government for many years at every station where there was a Government official to place a rain gauge, and to keep a record of the rainfall. The records were in some cases kept by incompetent men, and they were not always very accurate, but they were readily available, and taking an average, year in and year out, they gave a very good record indeed for irrigation purposes. Mr. Hollis had referred in his paper to an exceptional rainfall which had occurred in two cases in 1888. He (Mr. Wagstaff) was in Central India in 1888, and in the district where he was they had a record on the 3rd July in Bundelcund of 11 inches in 17 hours. That was an almost identical case.

Mr. J. BERNAYS said that, in connection with the measuring of the water over the gauges, it would be interesting to know to what height of water either kind of gauges was applied. He meant at what height or volume of water it was found convenient to substitute the square notch for a number of V notches when measuring. With regard to the piezometer tube, he had no doubt that in practice the inner end of the horizontal tube was carried much further away from the weir than was shown in the illustration, because it was very obvious that with water rushing over a weir, the height just over the edge was less than that representing the hydraulic head, which latter was the measurement needed for calculation.

M. W. H. HOLTTUM asked if the author could supplement his paper with information as to the geological features of the country. It seemed to him that the paper was confined to the gauging of the quantity of the water, and did not deal in any way with the preservation of the source of supply. He had had that point in his mind particularly. Suppose an engineer contemplated building a dam, so as to raise the water at the side of a valley 100 feet, but in the natural condition of things the rock should prove to be fissured at some intervening height, rendering escape and waste of water probable, was there any investigation made to provide against that contingency, and how were the fissures traced and dealt with?

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* Since the meeting Mr. Price has written to say that this statement refers to the year 1872, when the records show rainfall at Styhead for the year 243·98 inches, but in commenting on this fact, Professor Symons says in his report that, had the record at Styhead been in the usual proportion to the general fall for this wettest year, the figure would have been 260 inches.

Mr. CHAMBERS SMITH said that it occurred to him, with regard to the rainfall in South Africa, that the author had omitted to give a point of importance, namely, the amount of rainfall which occurred in any given limited time, such as the amount per hour. That was well known in England. We got occasionally a fall of rain amounting to one inch in one hour. Information as to the rainfall in South Africa, in order to be of any use, ought to state the quantity in a limited period of time. If that was not given, the provision against flood, which it was so necessary to take, could not be taken.

Mr. HOLLIS, replying upon the discussion, said that the major portion of the rainfall occurred during the months of June, July, and August, and, as a rule, if there was any exceptionally heavy fall, it occurred in one of those three months. That was at the Cape. He was not speaking of districts further north. He had several times read over one inch an hour at Steenbrass River, and in heavy rain had taken the readings every quarter of an hour. The Government had now a fairly complete system of rain-gauges over the whole peninsula. Those gauges were read once every month.

He had no reason to doubt the accuracy of the figures which he had given from 'The Cape Times.' He was at Cape Town when they were taken. At any rate, they showed that there was an exceptionally heavy fall at the time.

With regard to the local government of the district, the suburbs were separate townships, and each had its own council, and, although they were really connected with Cape Town, they had separate systems of drainage and water supply.

As to the governments in new countries taking immediate steps to obtain meteorological observations, of course that would have been very difficult in South Africa on account of the extent of the country to be looked after.

With reference to taking the lowest recorded amount of rainfall in one year for obtaining a safe basis to work on, that would depend on the number of years for which the records were available, which would of course apply chiefly to such a country as South Africa.

He could quite understand, with regard to the piezometer tube, that theoretically the height of water flowing over the gauge would vary from the amount one would read on the tube, according to the rate of flow of the stream, but the variation would be comparatively slight, and would be hardly worth taking into account when they were dealing with a large and fluctuating flow of water.

The geological formation at Steenbrass Valley was a very hard sandstone. With regard to making geological investigations, there were several large trial holes sunk on the site of the proposed dam, and taken to a considerable depth—20 feet or so.

PRELIMINARY INVESTIGATIONS FOR WATER SUPPLY.

BY SYDNEY A. HOLLIS.

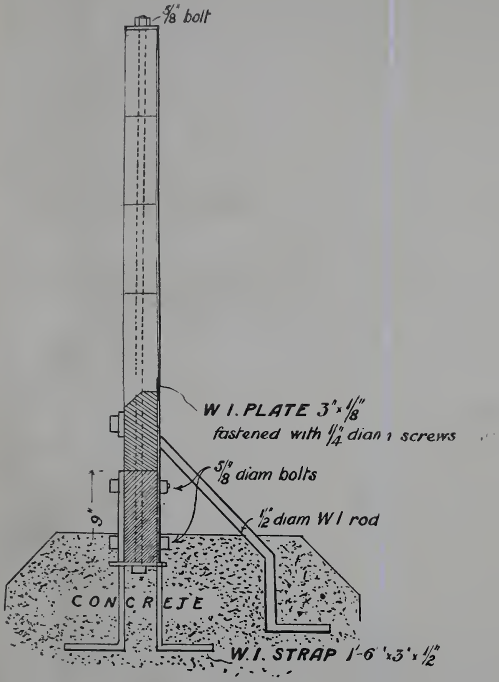

FIG. 1.

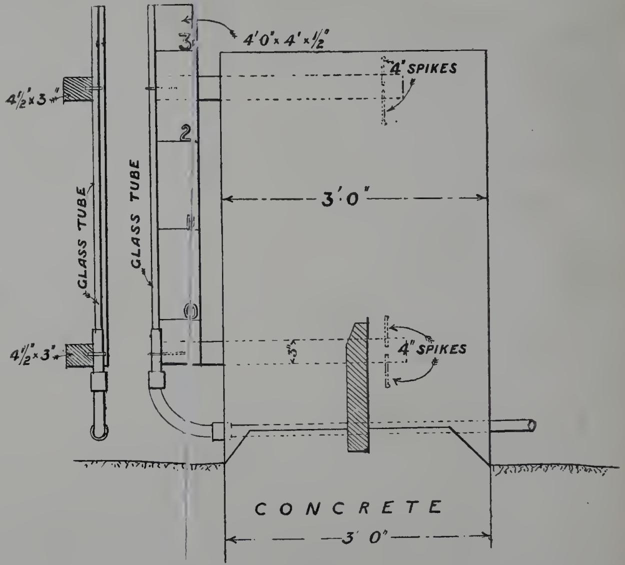

FIG. 2.

October 7th, 1901.

CHARLES MASON, President, in the Chair.

IRRIGATION WORKS IN SOUTH AFRICA.*

By J. Freebairn Stow.

At the present time, when the interest of practically the whole civilised world is centred in South Africa, it may interest the members of the Society of Engineers to have a description of certain works carried out by the Irrigation Branch of the Public Works Department, Cape Colony, of which the author was for some years an assistant engineer.

The Report issued by the Royal Commission recently appointed to inquire into the question of the settlement in South Africa of time-expired soldiers, emphasises the necessity for irrigation as a means of insuring successful land culture for intending immigrants, and as the subject is one of great importance to engineers who may be called upon to design and construct the necessary works, the author will describe some of the engineering difficulties to be encountered, and will give a description of the first and successful scheme of irrigation carried out by the Government of Cape Colony.

The first great advocate for irrigation in South Africa was the late Mr. F. H. S. Orpen, who for many years was Surveyor General of Griqualand West, and who retired in 1886. Mr. Orpen was ever a great advocate of irrigation works, and for years urged upon the Government of the day not to neglect the great wealth in the waters of the Vaal River—the greatest of all South African waterways—which hourly ran to waste. The Government investigated the matter, and ultimately, in 1889, a scheme for throwing a dam across the Vaal River at a point some seven miles above the township of Douglas and about 80 miles S.W. of Kimberley, was submitted by the late Mr. Bain, C.E., one of the Government District Engineers. The scheme was accepted by Parliament, and the necessary funds were voted for the dam, headworks, and irrigation canal. A rubble dam was constructed, and the canal—some eight miles in length—was made. The first great flood, however, destroyed the dam and played havoc with the canal. The inquiry instituted by the Government into the failure showed that no accurate sections had been prepared, and that the ground through which the irrigation canal passed was not adapted for its intended purpose. A portion of the line lay at the feet of high kopjes, and no provision had been made for passing under or over the canal the immense volumes of rain-water which in the wet season rushed down the hills into the valleys. The dam itself was built of loose rubble and pitched at such an angle across the river as to court certain failure. It is to be regretted that over £10,000 was uselessly expended on the work.

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* A Society's Premium was awarded to the author for this paper.

In 1892, the Government consulted Mr. H. C. Litchfield, M. Inst. C.E., an engineer of experience in irrigation works, who submitted plans for a masonry weir, an alteration in the line of the canal, headworks, bye-washes and storm overflows, and other necessary works. This scheme having been adopted, the author was sent to Douglas to take charge of the construction of the works under Mr. Litchfield. After carefully surveying and levelling the ground through which the canal was proposed to be constructed, the cutting up into plots of the irrigation area, situated about two miles below the township of Douglas, Mr. Litchfield commenced investigations as to the proper site and line for the masonry dam. A spot was selected about half a mile below the old or existing dam, and a line was set out. The fact that no contractor for public works would undertake the construction, compelled the Government to execute the work departmentally by direct labour, and the manner in which this was done may prove interesting.

Three hundred convicts from Cape Town Breakwater, under the charge of a superintendent, and numerous subordinate officials and warders, were despatched to the site of the proposed works, and lodged in marquees, surrounded by fences of entangled barbed-wire. The Public Works Department paid to the Convict Department one shilling per head per day for the hire of the convicts, the former department finding tents and other accommodation required. The Civil Commissioner of Herbert visited the camp weekly, when all cases of insubordination were investigated, complaints adjusted, and the whole convict camp thoroughly inspected. A medical officer was in constant attendance, and, taken all round, the arrangements were admirable, and were justified by subsequent results. Masons, fitters, gangers, blacksmiths, etc., were attached to the camp, and under their superintendence the convicts worked in gangs. Orders were delivered by the author each evening after sunset to the superintendent of convicts, as to the various kinds of work to be executed during the following day, and the gangs were despatched accordingly. The works being nearly fifty miles from the nearest railway station, the cost of transporting material to the works from Cape Town was very heavy. Especially did this apply to the large consignments of cement used in the construction of the masonry work of the scheme. The convicts at first made several attempts to escape, but recapture and heavy punishment soon put a stop to the practice.

On the north bank of the Vaal, within a few yards of the site of the dam, a quarry of splendid building-stone was found, and from this quarry every stone used in the construction was taken. The stone resembles that obtained at the quarries of Inverkeithing, N.B. It is very hard, but is admirably suited for the masonry. The width of the river at the point selected for the dam is 614 yards, and this can practically be taken as the length of the structure, the ends being built well into solid rock on either side of the river. The masonry was snecked rubble, the stones being hammer-dressed in the quarries, and laid in strong cement mortar well grouted in, each stone breaking joint in every direction. The greatest height of the dam in any part of the river is 14 feet; its breadth on the crest being 3 feet 6 inches, widening 1 foot for every yard in depth in regular offsets. The work was commenced simultaneously from both ends. Owing to periodical freshets in the river, great care had to be exercised during construction, and telegraphic communication was arranged from stations higher up the river, in order that the coming down of the water might be notified in time.

The method adopted for building the dam proper was as follows: A loose rubble dam was thrown across the river just below the line of masonry, and which was afterwards demolished and formed part of the down-stream slope of the wall. On this dam a tramway road was laid, and building materials from the quarries, cement, etc., were transported. During the freshets work had to be periodically abandoned, the rails taken up, and the gangs employed on the dam temporarily transferred to the irrigation canal, headworks, etc. The bed of the river being almost entirely solid rock, with the exception of several patches of diamondiferous blue clay, no difficulty was experienced in obtaining a solid bottom for foundations.

The cofferdams used were somewhat novel. Ordinary grain bags—some hundreds of thousands were used—were filled with clay puddle, and lowered into position on the line of the dam in sections of about forty lineal feet. Two feet outside this line another row of bags was placed, and clay puddle well rammed down between the two bag-walls. The water was then pumped out, all vegetable matter, loose pebbles, and other refuse removed, and fissured rock carefully taken out, blasting in some cases being resorted to. On the foundation thus formed cement concrete was laid to fill up inequalities in the bed rock, and the masonry was built. The crest of the weir was accurately levelled so as to present one true and uniform surface, and the upstream face of the wall, which had a straight batter, was thoroughly pointed up. Rubble was then packed carefully by hand against the down-stream face of the wall with a batter of 1 to 1. This in turn was backed with a long slope of 3 to 1 formed with carefully selected stones, and planted in the interstices were plants and reeds taken from the numerous rocky islands of the river. As soon as the masonry had set the bag cofferdam was demolished, as many of the bags as possible were re-used, and another section prepared for the masonry. So strong was the work that, although the stones in the crest of the weir were not dowelled, the heaviest floods, accompanied by severe shocks caused by floating logs striking the wall, did not disturb a single crest stone, which were all massive blocks carefully selected and built in.

As the work progressed great difficulty was experienced in building the cofferdams owing to the depth of water, and the convicts engaged on this work were told off in two-hour shifts, each shift being refreshed with coffee during their periods of rest. The temperature of the water was very low, and those who know what a South African winter is like will appreciate the difficulty of working in it. When the time arrived for the closing up and building in of the final section of masonry, the author found the current so strong and the rushing of water so severe as to render a puddle-bag dam useless without further contrivances. He therefore ran out from the northern bank of the river another loose rubble temporary dam above the point where the final closing up was to take place. Against the upstream face of the dam, which lay with a natural slope, bundles of long reeds, bound together with wire and weighted, were laid in vertical layers, and outside this some hundreds of loads of quarry spoil and earth were tipped, which lowered the level of the water, broke the force of the stream, and enabled the men to construct another puddle-bag dam just above the line of masonry. This method resulted in complete success. Four openings were left in the masonry until the last section was constructed, when they were closed with specially constructed concrete shutters working in guides, which had been built in during the progress of the work. After these had been lowered into position, the rest of the openings were built in with masonry in the usual way. The dam proved to be practically water-tight and the level of the crest accurate.

With regard to the canal, the author may observe that the water entered it 12 feet in width at its base through head sluices, and ran along the first section until reaching a deep valley, which was crossed with semicircular steel fluming. Masonry abutments were built on either side of the valley and piers between. On these rested disused railway metals 64 lb. to the yard. These were braced with light section tram rails 12 lb. to the yard, and on these were placed cast-iron saddles to receive the fluming, which was made in sections, sent up from Cape Town, and bolted together and fixed by workmen from the camp. The excavation throughout a length of 5 miles was in solid rock, and necessitated tedious drilling and blasting. The use of dynamite on public works being forbidden by the Government where convicts are employed, roburite was used with satisfactory results, although roburite is not, in the opinion of the author, as useful a blasting agent in rock cuttings as dynamite.

Great care had to be exercised in making provision for carrying the storm-water off the kopjes under or over the canal. Where the levels permitted box culverts were built, and in other cases super-passages were substituted. The latter were built in dressed masonry across the canal in the form of an arch, and covered with 18 inches of cement concrete to prevent scour when the heavy rains were falling. They also acted as a means of communication for foot or cart traffic, the passage of cattle and sheep across the canal, and in reality were relief water passages and bridges at one and the same time. The line ran for nearly 2 miles along the side of precipitous kopjes, the canal at this point being constructed in scarping.

A retaining wall of rubble masonry in cement mortar, well backed with earthwork, was built along one side, the remaining wall of the canal being formed by trimming and shaping the hill-sides. On approaching the township of Douglas the geological character of the country assumed a complete change, the formation consisting of sand overlaying a slatey marl. Although the fall of the canal was only 1·3 foot per mile, great difficulty was experienced in keeping up the slopes where the sandy formation was met with, and these were all pitched with stone. The outlets to the irrigation area were built in the form of box sluices, and ran on iron shutters working in guides.

The great features of the works, which entailed an expenditure of £36,000, are the manner in which the transport of materials, over one of the roughest sites for engineering works in South Africa, was conducted; the absence of red-tapeism, so often found on a Government Public Work; and the way in which convict labour, properly handled, was used to execute work, which if carried out with free labour would have cost an immense sum.

The author has not gone into the question of any theoretical problems which naturally arise in the design of all engineering works, but has simply endeavoured to place before the members a short practical account of the construction of what was really the pioneer scheme of irrigation in South Africa. The result has been that thousands of acres of parched veldt have been placed under cultivation, and the population of Douglas has been nearly doubled.

The works are under the charge of a local governing body, who have, as engineer and manager, an officer appointed and paid by the Public Works Department of the Government. So satisfactory does the question appear to the Government, that a large staff of engineers, under the direction of an expert in irrigation engineering, had, for the last four years prior to the outbreak of the war, been engaged in surveying and preparing likely schemes for submission to the Government. The more important of these were schemes at Oudsthoorn, Kenhardt, Van-Wykes-Vlei, and Steynsburg. Without irrigation, immigration, so far as Cape Colony is concerned, will, in the author's opinion, on the close of the war be a failure.

DISCUSSION.

The PRESIDENT said that the best thanks of the Society were certainly due to Mr. Stow for his excellent paper. The author had referred to the importance of preliminary investigations. He (the President) thought that any engineer was to blame if he promoted a scheme without having made his investigations as thorough as possible. Mr. Stow's paper gave an example in which 10,000*l*. was lost through the neglect of that essential work. He would move a vote of thanks to Mr. Stow for his paper.

The vote of thanks was carried unanimously.

Dr. H. R. MILL said that any remarks which he had to make would be of a theoretical or general kind, as the subject of the paper appealed to him on account of its scientific rather than its engineering interest. To his mind there was nothing in which the engineer had done more in the way of benefiting humanity than in rendering the water supply of a country available for the use of the people who dwelt in towns, or for the purpose of irrigating the ground in arid districts. Probably no one who had not gone into the subject from a geographical point of view had an adequate idea of the immense areas of the earth which were deficient in rainfall and consequently in water supply. The case of South Africa was much like that of Australia or of southern South America. In all three there was a fringe of relatively heavy rainfall on the coast, where the supply of water was ample for agriculture; but towards the interior the country became more and more arid, and the rains more and more capricious. That was one great drawback to the successful cultivation of the inland parts of South Africa by the British. The ordinary farmer in England had, as a rule, too much rain rather than too little, and all his agricultural methods were based on that fact. When he went out to a place where there was no rain during many months, he was absolutely helpless unless the engineer provided means for irrigation by supplying water where it was required.

The paper was extremely timely, because it seemed, after the terrible experience of the last three years, that South Africa was really on the verge of a great development; but if that were to be so it must take place not only by the yield of gold and diamonds but by the awakening of what was ultimately of much greater value—the agricultural productivity of the soil. Water was really worth a great deal more than diamonds in South Africa, and if water was wisely distributed over the surface of South Africa it would, in the future, bring in far greater returns, and benefit an enormously greater number of people than all the mines could support. The moral of the paper seemed to him to be to impress the importance of preliminary investigation, not only by the engineer but before the engineer. He had urged again and again—and as recently as a fortnight ago at the meeting of the British Association, in Glasgow—the duty that lay upon the Government of making preliminary surveys in all parts of the British dominions. Engineers in this country benefited so much by the Ordnance Survey, that it was difficult to conceive of a place where there were no maps to be referred to when works had to be executed, and where the engineer had to go himself to the untouched surface of the country, and make his surveys over a large area before he could tell even where his reservoirs could be placed, or how his aqueducts should run.

Whenever a new country was taken over, a survey ought to be made at the public expense. In countries with a small population the Government ought to take the earliest possible opportunity of fixing up rain gauges and making meteorological observations. If that had been done in South Africa when we took possession of the country, nearly a hundred years ago, we should have had no difficulty in knowing exactly how large the reservoirs ought to be, or where the natural conditions made irrigation an absolute necessity. In arid countries particularly the annual variations in rainfall were great and irregular, and a longer period of observations was required in order to calculate a true mean rainfall than in the happier climate of this country. He trusted that before long the necessity for making observations would be so driven in upon the governments of our colonies that they would make adequate provisions to secure preliminary data for engineers who had to carry out great works.

Professor J. Logan Lobley said that it had always struck him very forcibly that irrigation might be a great power in the world for increasing the productiveness of the land. If they could increase the productiveness of South Africa, they would add very much to the resources of the British Empire. There were many countries besides South Africa which would be benefited by irrigation. He had found in the interior of Spain an enormous amount of land which was practically useless for want of rainfall during several months of the year. He was quite sure that Spain offered a very fertile field for engineering in the way of irrigation works. Spain had a high table-land in the centre, and above that table-land there were high mountains which were capped with snow during a considerable portion of the year. The snow gradually melted and afforded a continuous supply of water for the main rivers; while the smaller rivers, rising in the lower ground, were quite dry during a considerable time. The main streams coming from the Sierras were supplied throughout the year. If that water was dammed at a high level, he was sure that an enormous increase in the development of the agricultural resources of Spain might be obtained. He might say, generally, that the work of the engineer was favoured very much by that of geologists, and that geologists always felt very greatly indebted to the works which engineers carried out.

Mr. J. Bridges Lee said there could be no doubt that pioneer papers, referring to new regions, would have a considerable future interest. He would ask Mr. Stow whether he could say how many miles of irrigation had been provided for, and what was the total fall. He understood that the average fall of the canal was one and a third foot per mile. In future, if they had too many small independent irrigation works started, tapping the Vaal River, or any other river in South Africa, to supply odds and ends of districts, there would be naturally a tendency to very great confusion: therefore he would venture to submit that, as in India, before numerous experiments of this kind were carried out it would be advisable that there should be some sort of general scheme extending over the largest possible area, for tapping the river at some convenient place, and providing for the disposal of the whole supply of water. It seemed practically certain that, otherwise, there must be some confusion, and that the different systems would tend to conflict one with another. No doubt Mr. Stow would be familiar with the kind of work which had been done in India and in Canada.

A great deal of work had been done in recent years in Canada, and, in that country, engineers had very largely availed themselves of photographs systematically taken over the whole ground. In Canada, photographs had afforded a very economical and extremely efficient way of mapping out the country for irrigation. In some of the publications of the Government of Canada in the Home Department, in recent years, there had been published some very interesting reports of the work done. He wished to inquire whether anything of the kind had been done in South Africa. He ventured to suggest that, if not, it would certainly be a good plan to prepare a preliminary photographic survey of the country. In a rough way all contour lines could be easily set out from the photographs. A certain amount of study was necessary to enable people to acquire sufficient facility in setting out plans and contours from photographs, but there were now, in different parts of the world, a number of people who had had actual experience in laying out lines of railway and roads and canals from a series of photographs.

Mr. S. A. Hollis said that Mr. Stow's reference to convict labour was interesting. The labour question was the chief obstacle in South Africa; but he had found from his experience in that country that, as a rule, convicts did less work than the natives. There had been some attempts at importing labour of different kinds, but they had not been successful. Some attempt was made by Mr. Rhodes just before the war, but it did not succeed.

Mr. G. W. **Willcocks** said that he knew the Vaal River very well, and that nineteen or twenty years ago he was engaged in South Africa on the construction of the Pietermaritzburg Water-works and the Kimberley Water-works.

There was one name which ought to be remembered in connection with water supply in South Africa, and that was the name of the late Mr. Gamble, who was there for several years as Chief Hydraulic Engineer for Cape Colony. He (Mr. Willcocks) was not acquainted with Mr. Gamble in South Africa, but later he had been Mr. Gamble's assistant, when Mr. Gamble was Chief Hydraulic Engineer in Ireland. He thought that it was only due to Mr. Gamble's memory that he should be mentioned in connection with the subject.

In the Vaal River the contractor for the Kimberley Waterworks used the same system for warning as to floods coming down as that which had been described. He should like to know what length of warning in days the author expected in his case. The source of the Vaal River was a great many hundred miles from where the intake of the Kimberley Waterworks was situated. The rivers in that country had an enormous rise. The Vaal River could at some places be waded across at ordinary times, but occasionally it became nearly a mile broad and 60 or 70 feet deep in the main channels. On the eastern side of Cape Colony he had in the dry season scratched in the sand of a river in order to get water. At other times that same river would come tearing down with a depth of about sixty feet of water, sweeping everything away in front of it.

With regard to irrigation, Mr. Gamble had two or three irrigation schemes. One was at a place called Fourteen Streams, and another was on the eastern side of Cape Colony, where he proposed a tunnel through a range of hills.

The dryness of the climate and the cessation of springs in South Africa were to a very great extent due to the destruction of the trees and the burning of the veldt. The Diamond Mines at Kimberley had consumed a large quantity of local timber for fuel. When the land was denuded of trees the mould was washed away, consequently the water ran off into the rivers. The surface of the ground, where it was clay, became baked into an impervious and hard crust, so that the rain could not percolate into the subsoil and replenish the springs.

Mr. D. B. **Butler** said that a point mentioned by Mr. Stow was the importance of making provision for the passing of rain-water in the wet seasons over or under the canal. He could not imagine how anyone could fail to allow for that. He presumed that the engineers knew something of the country before they designed the work, and the indications of storm-water coming down the sides of the kopjes must have been patent to the most careless observer. He had recently been travelling in Switzerland, where the kopjes were perhaps rather high, and everywhere provision had to be made for the winter torrent to pass either under or over the railways and roadways, winding up the valleys and by the foot of the hills. Those torrent-beds were quite dry at the time he saw them, but evidence of their destructive power was apparent from the immense boulders carried down in time of flood.

Another point which had occurred to him was as to whether there was any local material available for the construction part of the work referred to other than imported cement, the cost of transport of which was so expensive. Was there no limestone near, which could be readily burned and converted into hydraulic lime?

Mr. Stow's description of the improvised cofferdam was very interesting, and was a very good illustration of an ingenious application of materials at hand. In out-of-the-way places, where there was no depôt to run to, it was obviously necessary to resort to make-shifts of all kinds.

Mr. J. Bernays said that it would be interesting to know the nature of the first dam that was destroyed by the great flood, and in what position it had been erected. The dam seemed to be but of little height, only 14 feet, which he supposed was measured from the foundation. That was very small for a dam, and there should have been no difficulty in making it not only water-tight, but perfectly sound. He had had to do with some dams in a mine in Portugal, one of which was about sixty or seventy feet high and eight hundred feet long. It was a regular rubble-masonry dam; no difficulty had been experienced in either keeping the water in or in guarding against freshets. Of course the investigations were carefully carried out beforehand. He would ask the author why the work in South Africa had been carried out in winter at all, or when there was a heavy rush of water down the river. At other times the water seemed very low indeed, and it would be useful to know why the erection of the dam had not been left to a time when it would be more easy to do the work.

He should like to ask also for some information about the method adopted for transporting the materials. In Portugal they had to use mules. In Iceland also, where the paths were very rough, mules were used for carrying materials. Those were two totally different countries, one being very hot and the other very cold; but in both cases mules were used. But, as Mr. Butler had said, it would be interesting to know whether some of the materials might not have been found in the neighbourhood, and transport thus have been saved.

Mr. J. Bridges Lee asked what was the length of the canal, and what was the total area to be irrigated by the works described by Mr. Stow.

Mr. Chambers Smith said Mr. Stow's paper was very interesting, but the author had confined himself to the structure of the dam. He thought, however, that the particulars which would enable an engineer to derive benefit from the paper were not given so fully as they might be. More detail might have been of use.

Mr. Stow, in replying upon the discussion, first dealt with Mr. Bernays's enquiries as to why the construction of the dam was carried out during the winter. He said that during the winter months, in the Douglas district of Griqualand West, where he was, there were times when the water in the Vaal River was at a very low ebb. In making a dam of that length where there were strong currents, they were obliged to work whenever it was possible to work, and whenever they got a chance, and very often night and day. They had telegraphic communication between Warrenton and Fourteen Streams which had been referred to by Mr. Willcocks. It all depended upon the kind of person in charge of the telegraphic arrangements at these stations whether they got a telegram at all. They could not, as a rule, impress upon these men the necessity of letting them know when the river was coming down. The river at Douglas was fed by the Brak River, the Riet River, and the Modder River.

There were three general methods adopted for gauging a stream. One was by notch gauges; another was by current-meters, which were not very often used, and which he did not believe in; and the third, was by taking careful sections of the stream and calculating the mean velocities. In a wide river, like the Vaal River, the last method was the only practicable one.

He was sent down the country after the works were completed to take charge of the Kafir Kuils bridge works. The canal completed then was eight miles in length, and the total fall was about ten feet.

The irrigation area laid out in irrigation plots was about 700 acres. All the schemes were based upon the assumption, as far as South Africa was concerned, that a discharge of one cubic foot per second would effectually irrigate 100 acres of land. The plots were laid out in square lots, each side measuring a little over 7 chains, and each lot being equal in area to 5 acres of English land.

With regard to the discharge in the canal, at flume No. 1, where the area was 8·9 square feet, the discharge was 1·3 foot per second, or 12,900,000 gallons per day. There were four of those flumes, and each discharged over 12 million gallons per day at a velocity of 2·4 feet per second.

As to the cement, the Government did not, at Douglas, adopt any works for its manufacture, because experiments had in the past cost them rather dear. The works upon which he was employed as assistant to Mr. Litchfield were works for remedying the mistakes of the past, and the Government did not feel inclined to try experiments in the direction of a cement factory for that small amount of masonry.

As to Mr. Bernays's remarks about the dams in Portugal, that gentleman must have forgotten that the construction of Douglas dam entailed working in water with a depth of never less than 5 or 6 feet. He thought that in such work as the construction of a masonry dam across a river like the Vaal, South Africa and Portugal could not be compared at all.

He could not agree with the remarks of Mr. Chambers Smith. If he had written a paper such as Mr. Chambers Smith suggested, he should have kept the members at the meeting all night.

The reason that the first dam was a failure was that it was constructed just below a sharp bend in the river, and any engineer would at once know what the result would be. It was well known that the proper position for such a dam was the straightest part of the river.

With regard to provision for the passage of storm-water from the kopjes over or under the canal, he could not say why that was left out. He believed that the engineer who was employed for the construction had been employed on the Ordnance survey, and had not had much practical experience of irrigation engineering practice. The water from the kopjes rushed into the canal in torrents, and it deposited silt.

With regard to the gauging of the streams, he must say that the Vaal River, in times of flood, was sometimes a mile broad and 60 feet or 70 feet deep. At the point of construction of the Douglas dam it was at times a mile broad. From the head works down to the first set of flumes, the whole of the canal was, at certain seasons of the year, under water, and it was absolutely necessary that adequate relief should be provided, and which was constructed partly through solid rock. Mr. Bain's canal near the head-works was made through sand and clay and such-like soil, and the first flood that came down washed the whole away.

As to evaporation and soakage, Mr. Litchfield estimated that they amounted to 2 inches per day. That meant nearly 256,000 gallons a day, 5 miles from the weir.

Photographic surveying was largely practised in Cape Colony at the present time, and it saved engineers a large amount of work.

November 4th, 1901.

CHARLES MASON, PRESIDENT, IN THE CHAIR.

THE MAIN DRAINAGE OF ILFORD.*

By ROGER GASKELL HETHERINGTON, M.A.

ILFORD presents a most marked example of the recent rapid growth of greater London, the population of that district having increased by nearly 35,000 during the last fifteen years. The district may be described as almost purely residential, there being exceedingly few factories of any kind. The houses are mostly small, being of an average rental of about 30*l.* per annum.

The first drainage scheme was prepared by the late Mr. Brundel in 1882, and was sanctioned by the Local Government Board in 1884. The population draining to the works of the Ilford and Chadwell Wards at the date of that scheme was 7500; it is now 42,000, and is increasing with great rapidity. Both the main sewers and the outfall works soon became inadequate to deal with the increased flow, and the works about to be described, which were designed by Messrs. John Taylor, Sons and Santo Crimp, are calculated to meet the requirements of a population of upwards of 100,000. In designing the present works, one of the first objects was to utilise to the full all the existing sewers and works, and this has had a modifying effect on the general scheme in several points.

The old scheme of main sewers may be roughly said to consist of two high-level gravitation sewers and two low-level sewers, the sewage from the latter having to be pumped. Of the high-level sewers, one runs east and west from Chadwell Heath to Ilford, and the other north and south from Barking Side to Ilford; these join in the town and run as one to the outfall works. The two low-level sewers collect the greater part of the sewage of the town itself and are of no great length. They fall to the old pumping station on the bank of the river

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* The Bessemer Premium was awarded to the author for this paper.

Roding, and the sewage is thence lifted into the high-level system. This old system has been left practically intact except for the diversion of about one-quarter of the low-level flow from the old to the new pumping station situate at the outfall works.

The drainage area may be roughly described as a flat plain, falling on the west to the river Roding, and on the south towards the river Thames, that is to say, the greatest fall is from north-east to south-west. The outfall works are situated in the south-western portion of the district, and are at such a level as to allow the sewage of about two-thirds of the total area to reach them by gravitation. This high-level portion of the scheme is provided for by three main sewers, two old and one new. The old sewers are: firstly, that running east and west from Chadwell Heath to Ilford, and, secondly, that running north and south from Barking Side to Ilford. The Chadwell Heath sewer runs along the old Roman road which connects Colchester and London, and practically contours the valley of the river Thames. This sewer is laid at the lowest level at which it is possible for it to reach the outfall works by gravitation, and so forms the southern boundary of the high-level area. The Barking Side sewer is a main sewer necessary for the drainage of Barking Side, and joins the Chadwell Heath sewer at Ilford.

The new high-level sewer runs from Claybury, on the northern border of the parish, to Ilford, and contours the valley of the river Roding at the lowest possible level for a gravitation sewer. It therefore forms the western boundary of the high-level area. This sewer runs practically parallel with the Chadwell Heath and Barking Side sewers from their point of junction to the outfall works; but from that point all these sewers are necessarily at too shallow a depth to deal with the sewage of the district through which they run. Thus the total area capable of being dealt with by gravitation is that portion of the parish which lies north of the old Roman road, with the exception of a narrow strip of land alongside the river Roding. This last portion is provided for by a sewer laid close to the river, and falling to the old pumping-station in the town. The southern low-level area is provided for by two sewers, both falling to the new pumping station at the outfall works. One of these practically follows the southern boundary of the parish, turning north for a short distance at its two extremities. The other runs east and west about midway between this and the high-level sewer. Such is a general description of the line of the various main sewers and their functions.

Looking at these sewers now in constructive detail, the author would observe that the Roding Valley low-level sewer had to be laid in ground consisting of ballast containing a very large quantity of water, and great care had to be taken to keep it water-tight, more especially as its flow has to be lifted 30 feet by the pumps. Hassel's double-joint pipes have been used, surrounded with concrete, and a 6-inch sub-drain laid. By laying this 6-inch sub-drain and then covering the bottom of the trench with a 6-inch layer of 5 to 1 Portland cement concrete, a very good bottom was obtained, and the making of a water-tight sewer in very bad ground was successfully accomplished.

The manholes were constructed in 9-inch brickwork, but below water-level an outer and independent 4½-inch wall was built, a ¾-inch space being left between these two walls which was filled in with 2 to 1 cement mortar. This was found to be most effective in rendering the manholes water-tight. In the construction of this sewer it was necessary to cross the river Roding twice, once in a very oblique direction. These river crossings were constructed of cast-iron socket pipes with lead joints, as also was that portion of the sewer between the two crossings, which was laid within a very few feet of the river. This double crossing of the river was necessitated by the difficulty and expense of obtaining easements at this point on the east side of the river. This sewer is constructed for the last 580 feet of its length as a 60-inch brick barrel, which acts as a night store for the sewage, allowing the pumps to be stopped at night, and it also equalises any sudden rush of storm-water. This brickwork storage sewer is constructed with two 4½-inch rings of brickwork with a ¾-inch collar-joint between them; this collar-joint was adopted to render the sewer water-tight. From the lower end of this storage sewer the sewage is taken through a 24-inch iron pipe to the screen chamber, where it is passed through screens with a ½-inch mesh. These screens are made of ⅜-inch flat bar iron, and are lifted vertically for cleaning by a chain and winch. The screens are in duplicate, so that one is always in position whilst the other is lifted for cleaning. The sewage, after passing through the screens, flows direct to the pump-sumps, which are only a few feet distant.

The pumps consist of two 6-inch centrifugal pumps working in separate sumps. Each pump is driven by belting direct from a 6 horse-power Crossley gas engine, and is capable of lifting 500 gallons per minute, the total lift being about 30 feet. Both pumps deliver into the same 12-inch cast-iron rising main which conveys their discharge for a distance of about 1600 feet into the high-level system. These pumps are in duplicate, but one of them is quite capable of dealing with the flow, thus giving one engine and pump as a reserve against any breakdown. The engine house containing the machinery was in existence for the old scheme, but has been enlarged for the new machinery. It contains, besides the pumps and engines just referred to, two 6 horse-power Crossley gas engines, driving two 5-inch centrifugal pumps. These pumps raise the sewage of the two old low-level sewers falling to this point, and discharge it into the high-level system through a 9-inch cast-iron rising main, running practically parallel to the new one.

Turning now to the two low-level sewers falling to the new pumping station at the outfall works. Both these sewers present almost the same details of construction as the one just described. The northernmost of the two consists of 12-inch and 15-inch pipes falling to a manhole directly to the north of the outfall works. From there it is continued as an 18-inch sewer. This 18-inch section is constructed with concrete tubes jointed with neat cement and surrounded with concrete. This surrounding concrete is formed as a block 27 inches square, giving a width of 3 inches outside the tubes at the narrowest point. These 18-inch tubes connect into a 48-inch brick barrel sewer, constructed in an exactly similar manner to that on the Roding Valley low-level sewer, and fulfilling the same functions. This in turn discharges through a 24-inch cast-iron pipe into the screen chamber, which is an exact replica of the one already described, except for the fact that the pump suctions are fixed in it instead of in an independent sump, as is the case at the Roding pumping station.

The more southern low-level sewer falling to the new pumping station hardly calls for any special comment, as it is practically a repetition of the one last described, but at a lower level. The two 48-inch brick barrels on these two sewers had to be constructed for a length of about 400 feet in the same trench, one quartered on the other. With respect to the pumping arrangements for lifting the flow of these two sewers on to the outfall works, there have been no existing works to consider, and a new pumping station has been built. This consists of one house with the floor at two different levels; on the upper level are two steam boilers of the locomotive type, which supply steam to the engines which are on the lower level. The engines consist of four direct-acting compound engines, two driving 6-inch, and two 9-inch centrifugal pumps. These pumps, as is the case at the Roding pumping station, are in duplicate, one pump in each case being capable of dealing with the whole flow of the sewer with which it is in connection. The 6-inch pumps are capable of lifting 800 gallons per minute through a lift of about 20 feet, and the 9-inch 1400 gallons per minute through a lift of about 23 feet. The two 6-inch pumps are in connection with the southernmost sewer, and the 9-inch with the northernmost. These four pumps all deliver through the same 18-inch cast-iron rising main into a manhole close to the engine house, whence their discharge flows down to the main inlet to the works.

The high-level sewers are constructed with concrete tubes and stoneware pipes, varying in size from 12 inches to 18 inches, and call for no particular comment with respect to their construction.

Turning now to the outfall works. These works cover an area of seven and a half acres, and are at a level of about 25 feet above Ordnance datum. To explain these works at all adequately it is necessary to give, in some detail, the several changes and alterations which have been made in them from time to time, as their present design depends largely on the form of the older works. As originally constructed the sewage was brought on to the works at the north-western corner, and conveyed for a distance of about 100 feet through a 24-inch brick barrel to the lime-mixing house. This house was a two-storied building, the upper floor being used as a lime store, and provided with a hopper shoot to convey the lime to the mixer on the lower floor. The sewage was brought through this building in a channel in the floor; this channel was some 2 feet lower than the brick barrel referred to, which conveyed the sewage to this point. This drop of 2 feet was utilised to drive an undershot water-wheel, which actuated the lime mixer, enough sewage being drawn into it to mix with the lime. This arrangement provided an automatic lime-mixing, which was then the only treatment the sewage obtained before passing to the settling tanks.

The settling tanks were four in number, and were arranged so as to work in series, except during the cleaning of any one, when a side channel was put into use. These tanks were situated immediately adjoining the lime-mixing house and were, in the case of the first two, 30 feet by 20 feet, and in the case of the others, 60 feet by 20 feet; they had an average depth of 4 feet 6 inches. The sewage passed into the first tank through an open channel; from the first into the second through openings at the bottom of the dividing wall; from the second to the third over two weirs, and similarly from the third to the fourth. From the fourth and last tank it flowed through two openings into a distributing channel. The effluent from the tanks was passed over the available land which was laid out as a filtration area. This filtration area consisted of the natural soil, which is sand and ballast, ridged and furrowed and sub-drained at a depth of 6 feet. After passing through the land the effluent was collected in the sub-drains and conveyed through a 15-inch pipe to the river Roding. The sludge obtained from the settling tanks was drawn off into a sump, whence it was lifted by a bucket pump into overhead wooden shoots and distributed to sludge beds, where it was allowed to dry, and dug in.

The rapid growth of Ilford after a time rendered these works inadequate. First the water-wheel had to go, as it restricted the flow of the sewage, causing constant flooding of the lime-mixing house. The filtration area also was inadequate, only a small percentage of the sewage finding its way to the sub-drains. The remainder flowed off the top of the ground, and had to be taken into the manholes direct to the effluent pipe. Such was the condition of affairs when Messrs. John Taylor, Sons and Santo Crimp were called in to advise, and the works next described have been constructed from their designs.

In the first instance the advice of the engineers was sought merely as to the works necessary to improve the effluent from the tanks and filtration area, and the works now to be described were recommended. Owing, however, to certain delays in commencing their construction, and a sudden abnormal increase in the population, it was found that when the works were completed they actually had to treat the sewage of a population greater than they were designed to deal with. Before entering into the matter of the treatment of the sewage as at present carried out, it will be well to point out that the sewage may be practically taken as entirely domestic, there being little or no manufacturing refuse to be dealt with. The surface water from the streets and roofs is in part dealt with by separate surface-water drains, but a large proportion of it is taken by the sewers, and this causes very considerable quantities of sand to be brought to the outfall works in time of rain, besides causing a very great increase in the flow, even during a moderate shower.

The works consist of a lime-mixing house, two engine houses, sludge-pressing house, three settling tanks, and four coke breeze contact beds. The sewage, on reaching the works, is carried through a 33-inch brick barrel sewer to the lime-mixing house; through this house it flows in an open channel fitted with six slate baffles. These baffles serve a double purpose, for not only do they fulfil their primary purpose of thoroughly mixing the chemicals with the sewage, but also, owing to there being a considerable fall in the channel, and therefore a quick flow through it, they cause much of the solid matter to be broken up, and thus enabled to pass the screens. The chemicals added to the sewage in the lime-mixing house consist of milk of lime and ferrous sulphate in solution; nine grains of lime and three of iron being added to each gallon of sewage. The ferrous sulphate solution is added from the barrel in which it is made, by opening a tap to different extents, to suit the varying flow of the sewage. The milk of lime is added from an automatic compressed air mixer which is worked from the air-compressors in one of the engine houses, to which reference will be made later. After leaving the lime-mixing house, the sewage flows directly into the distributing channel which runs alongside the tanks. As it enters this channel it passes through three screens with ½-inch spaces, and these remove practically everything which is too large to eventually go to the sludge presses. This distributing channel runs alongside the settling tanks of which it forms an integral part, there being openings into each tank fitted with sliding iron doors so as to allow any tank to be shut off for cleaning.

The tanks are each 100 feet by 60 feet, and have an average depth of 5 feet 6 inches, their total capacity being 600,000 gallons. These tanks are worked on the continuous system, two tanks being always in use and one shut off for cleaning, each tank being worked four days and closed two. Each tank has a weir wall extending across its whole breadth, on the side opposite to the inlet openings, over which the effluent flows. The tanks also are provided with two sets of scum boards, one set, formed of planks floating vertically in slots, is placed about one-third of the length of the tank from the inlets. The other set of scum boards is fixed to the weir wall and at a distance of about 2 inches from the same.

The manner in which these tanks are worked is as follows. Two tanks are always in use and one always in the process of being cleaned. The tank to be cleaned is shut off; the contents are then drawn down as low as possible by means of a floating arm fixed at the highest end of the tank; this arrangement allows the top portion of the settled effluent to be drawn off without disturbing the settled solids. The solids so left in the tank form a very liquid sludge. This sludge is drawn off through a penstock into the sludge culvert which runs alongside the tanks at their low end. The fact that the tanks have a fall of about 3 feet in 100 feet and are entirely rendered in neat cement, allows the sludge to be easily swept out of them into the culvert, and also enables the tanks to be most thoroughly cleaned with a minimum of labour, for all that is necessary is to sweep the walls and floor, after they are dry, with a broom. The sludge culvert terminates in a sump in which a bucket pump works; this bucket pump raises the sludge into an overhead iron tank, in which it is allowed to settle for a short time. This settlement allows about half its bulk to be drawn off from the top stratum as a more or less clear liquid, which is run back again into the distributing channel and so into the tanks. The sludge which remains in the tank is taken down to the pressing machinery.

The sludge-pressing installation consists of two Crossley 4 horse-power oil engines, two air-compressors, one high and one low-pressure, two sludge rams, and three presses. The two oil engines and air-compressors are in a separate house adjoining the sludge-pressing house, and supply compressed air to the pressing machinery at a working pressure of about 80 lb. to the square inch. These air-compressors also supply the compressed air for the lime-mixer in the lime-mixing house. The sludge is drawn down from the overhead tank to one of the sludge rams, where it receives a dose of lime; the ram is then closed, and the compressed air turned on. This forces the sludge up through a 3-inch pipe to the presses. In these presses it is forced against jute mats, which retain all the solid matter and allow the liquid to flow out into troughs, whence it is taken back to the distributing channel and passed again through the tanks. After a charge has been passed through the press, the compressed air is turned off and the press opened. The sludge cake is then dropped into a truck and wheeled out and stored. The dealing with the accumulation of this sludge cake offers considerable difficulties, for although it causes no offence, it takes up a large amount of storage room. It seems impossible to turn it to any use, as the manurial value is small, and the market gardeners do not think it worth the expense of carting it as manure.

The sewage effluent, after treatment in the tanks, flows over a weir wall into an effluent channel, whence it is passed into coke contact bacteria beds. These contact beds are four in number, three high-level and one low-level. The high-level beds dealing with the ordinary sewage flow are each about one-third of an acre in extent, and are filled with coke to a depth of 3 feet 6 inches. The fourth, or low-level contact bed, which only takes the effluent drawn off through the floating arms when one of the tanks is emptied for cleaning, is 920 square yards in extent, with coke 3 feet in depth. These contact beds were constructed by simply excavating the ground and forming banks around them. In the bottom of each was laid a system of open jointed socket drain pipes, laid in very shallow open channels. These drains increase in size from 3 inches to 12 inches as they reach the outlet, each outlet opening into a manhole controlled by a penstock. The contact beds, as first constructed, had only a depth of 3 feet of coke, the extra 6 inches being subsequently added. The coke used had to be coke breeze, or hard clinker, broken to pass through a ring half an inch in diameter, and afterwards screened to remove the fine dust. The extra 6 inches which was afterwards added consisted of coke breeze three-quarters of an inch instead of half an inch. The tank effluent was at first run into each contact bed through an opening in the effluent channel, but wooden carriers were afterwards added to distribute the liquid more evenly. The effluent, after passing through these beds, is conveyed through a 15-inch pipe to the river Roding.

The method of working these beds is as follows:—The outlet from a bed is closed and the bed charged; it is then shut off and another bed is charged. After the effluent has stood in the bed about one hour the outlet is opened and the effluent drawn off. The bed is then allowed to rest until after the third bed is charged, when it is again put into use. It will be noticed that the period of contact allowed is only one hour, and from the results obtained there can be no doubt that this period is too short. The period of resting empty is also exceedingly small, but neither the contact nor the resting periods can be increased owing to the rate of sewage flow. As before stated these beds have to deal with a much larger quantity of tank effluent than was originally contemplated.

The foregoing shows the manner in which these works were designed to be used, and in which, with certain modifications, they have been used during the last three years. It will now be necessary to go into their history shortly during these three years in order to explain the modifications now being carried out. As before explained these works were, at the very outset, obliged to deal with more sewage than they were designed for, and very shortly the contact beds showed signs of being overworked, and did not produce an entirely satisfactory effluent considering the small stream into which it had to be discharged. In the spring of the year 1900 the Urban District Council determined to use the tanks as open septic tanks, and consequently stopped all chemical treatment and pressing for six months. The capacity of these tanks, which were designed for chemical treatment and not for the septic process, is only about half what is considered necessary for this process. At the end of the six months the tanks were found to be practically full of solid matter; in fact such was their condition that a man was able to walk across them. The sewage flow had made small channels for itself through the body of the solid sludge, and only passed over the weir wall at certain places. The effluent leaving the tanks was very foul, and contained a large amount of suspended matter. At this period it was necessary that the tanks should be cleaned out, which proved a long and noxious process, and in the autumn of the same year they were again run as open septic tanks, and were found, on this occasion, to have filled up in four months. Apparently the difference of two months in the time taken for them to fill up was caused by the different temperature, the septic tank principle working better under the hotter, than under the colder conditions. After this, chemical treatment and pressing were again reverted to.

The result of this experiment on the coke contact beds, already over-worked, was disastrous; they became seriously clogged, and their capacity was not more than half their original capacity. The beds being in this condition, the effluent, as might be expected, was not what it ought to be, and, on the advice of Dr. Thresh, Medical Officer of Health for Essex, chloride of lime was added to it as it left the works. Another difficulty had also arisen owing to the volume of the sewage, the 15-inch pipe from the sewage works to the river Roding had become inadequate. Under these circumstances it was decided, under the advice of the engineers, to put in an entirely new outfall, and to carry the effluent a distance of about three miles through the parish of Barking direct to the tidal waters of the river Thames, the outfall being situated a short distance below the London Northern Outfall at Barking Creek. The discharging of the effluent direct to the tidal waters of the Thames avoids the necessity of further purifying the chemical effluent; that is to say, after treating the sewage chemically in the tanks the effluent as it leaves them will be disposed of direct instead of being treated on contact beds. This will throw the present beds out of use during dry weather flow, and allow them to be used as streaming filters for storm water, their outlet to the river Roding being retained. It is proposed to build new tanks, similar to the existing ones, giving a total tank capacity of about 1,800,000 gallons, equal to rather more than 24 hours flow of the dry-weather sewage.

The new effluent pipe is about 3 miles in length and is 30 inches in diameter. For the first half mile of its length it is constructed with concrete tubes surrounded with concrete, and for the remainder of its length cast-iron pipes are employed. This effluent pipe is laid with a fall towards the Thames for the whole of its length, except in two places in which the nature of the ground has necessitated inverted syphons. The first of these syphons is under the brook at the foot of the outfall works, and is only a few feet in length, being about four feet deep. The second syphon is considerably longer, and is necessitated by a valley crossing the line of pipe; it is about 800 feet in length, and in this case the pipe is laid down and up the slopes of the valley, the bottom of the syphon being about 10 feet below the general gradient. With the exception of these two syphons the pipe has a fall towards the Thames at all points varying from 1 in 500 to 1 in 5400 on Ripple Marsh near the point of outfall. There are eight manholes on this effluent pipe, three of which are sealed and connected with ventilating columns, to comply with the requirements of the Barking authorities, in whose parish they are situated. Although this pipe is laid with a fall as described, direct lines, as in a sewer, have not been adopted, but the pipe follows the curves of the roads, as it has not to carry any solid matter. This pipe will deliver at a level of 1 foot below Ordnance Datum low water mark at its point of discharge, being about seven feet below Datum. This outfall will have a free discharge for about eight hours out of every twenty-four. Of course, apart from this free discharge it will discharge at any time when the head of water in the pipe is greater than in the river. When the pipe is tide-locked, it will act as an effluent storage sewer. It may be here noted that the inlet at the outfall works to this pipe is 3 feet higher than the highest recorded flood tide at Barking.

The fact of this effluent drain passing across Barking Levels and through the Thames retaining bank has necessitated exceptional precautions being taken against any failure in the pipe, as such a failure would mean admitting the tidal waters to an exceedingly large tract of land which lies below high tide level. The precautions adopted are as follows. First a large and exceedingly strongly built chamber has been constructed just within the Thames retaining bank, and is carried up to a greater height than this bank. This chamber is 10 feet by 8 internal measurement, and is divided into two compartments, into the first of which the effluent pipe discharges. The effluent is taken through the dividing wall into the second compartment by two pipes each 21 inches in diameter; these two pipes are each fitted with a sluice valve on their inlet end and a tide flap on their outlet end, thus giving a double check on the tide water, one being automatic. From the second division of this chamber the effluent is again conveyed by a 30-inch pipe through the river bank, and immediately outside the bank a 30-inch reflux valve is placed, thus forming a third check on the tidal water. Thus, assuming a burst on the main there are three very efficient and independent checks to prevent the ingress of tidal water. The effluent, after passing the reflux valve, discharges over a channelled concrete apron into the river.

The construction of this effluent drain offered no peculiarities north of Ripple Marsh, but in crossing the marsh bad ground was found, consisting of an admixture of clay and peat to below the depth at which the pipe was laid; below this there was peat overlaying the Thames ballast. It was not considered safe to depend on this ground to sustain the weight of the pipe unaided, therefore at each joint-hole the ground was taken out 5 feet by 4 feet, and to a depth of 1 foot below the pipe. Each of these joint-holes was filled in, after jointing the pipe, with five to one Portland cement concrete, thus forming at every twelve feet a flat base for the pipe measuring 5 feet by 4 feet. At one portion of its length on Ripple Marsh the pipe passes under some old rubbish shoots for a length of about 300 feet. This portion was laid in heading, the heading being taken out 1 foot below the invert of the pipe. Turned and bored joints were used in this length, and the pipes were all put in from one end. Each pipe was brought in on a trolley and put in position, then the next pipe was used to drive it home, being bumped up against it, wooden packing being placed between. After each pipe was in position and home, being then carried on packing, concrete was placed under it to fill the 1 foot space, and afterwards the packing was removed, and the heading refilled. This method, though not very expeditious, proved very satisfactory.

This scheme of dealing with the sewage of Ilford presents, possibly, some interesting points in meeting the problem which is ever recurring, namely, the treatment of the sewage of an area with a rapidly increasing population without discarding the existing system which was never designed for great enlargement.

DISCUSSION.

The PRESIDENT said that the paper had interested him very much, as he had himself been connected in the past with large sewage schemes. Ilford had grown phenomenally. The rate of progress was almost a byword to those acquainted with statistics. Therefore, to devise a satisfactory scheme of sewage to deal with such a rapidly growing population must have been a matter of great difficulty, and must have required a very large amount of forethought.

The quality of the sewage, as he gathered from Mr. Hetherington's paper, was mainly that which they generally got from an entirely domestic population. There were no factories to deal with, which simplified the treatment of the sewage at the disposal works. In his opinion a little more explanation was required as to the plans referred to by the author. He did not quite follow the lines of the new sewers. A description of the old sewers was given, and the new sewers were shown on the plan, but as to several lines it did not appear whether they represented new sewers or old ones. He took it that the old pumping station on the river was retained, but he could not see how the sewage got from there on to the outfall works.

It occurred to him from the paper that there had been outside influences at work over which the engineers had no control. For instance, they heard of a septic tank having been tried for twelve months; the sewage matter being in a complete state of chaos in those few months, that could not have occurred if the engineers had been given a free hand. The author had told them that the liquid was trickling in channels through the solid matter. If he would tell them how it came to that state, and why the septic tank was tried and not fully adopted, it would be useful. He concluded by proposing a cordial vote of thanks to the author of the paper.

The vote was carried by acclamation.

Mr. G. MIDGLEY TAYLOR said that he had not intended to make any remarks, for the scheme described in the paper was one in which he had been concerned; but he would refer to one or two matters mentioned in the paper involving general principles.

In the first place, he should like to mention, that during the construction of the first works there was an increase in the population of about twenty-five per cent. in one year. At the beginning there was very considerable delay, through the Local Government Board and from one or two other causes, and when the purification works were completed they were actually dealing with four thousand more people than they were designed for, and further extension became necessary.

Mr. Hetherington in his paper referred to the experiment of working tanks as septic tanks, and stated that at the end of six months the tanks were practically full of solid matter; and, further on, he said that the tanks filled again in four months. The author attributed the difference in time of filling to the variation of temperature. The variation of temperature had a very important bearing both on septic tanks and the bacteriological treatment of sewage. The sewage at Bombay, which city he had lately advised, had an average temperature approaching 76 degrees Fahrenheit, and there it was found that in a septic tank the reduction of the albuminoid ammonia, even after four hours' storage, was something approaching 81 per cent.; whereas in England, according to Dr. Rideal (who had made a vast number of experiments on the septic tank system which was put down in Exeter), an average of only about 46 per cent. reduction in the albuminoid ammonia could be got.

Again, when they came to the question of contact or streaming beds, temperature had very much influence upon them. In India about fifteen minutes through a streaming filter resulted in 95 per cent. of purification, and a large amount of nitrates present with the effluent, which, of course, showed great purification.

Colonel Duckett, a late inspector of the Local Government Board, in his filter, realised the importance of the influence of temperature, but he, the speaker, felt that endeavours to raise the temperature of the whole body of the sewage by flues and furnaces was beyond the capacity of the engineer in this country. With regard to the experiment of running with septic tanks, that was not made under the advice of his firm, but it was tried as an experiment by the District Council. As far as the experiments could show, there was certainly not more than 10 per cent. of liquefaction. The result was that the tanks rapidly blocked up, and, as Mr. Hetherington had told them, a man walked across them. The cleansing of the tanks was an operation that was not lightly to be undertaken. It was very offensive work.

The author referred to the question of putting in a new outfall and carrying the effluent three miles away into the tidal waters of the Thames. At Ilford there was a small stream of clear water immediately below the works discharging into the River Roding. If they wished to discharge their effluent into that stream they had two courses open to them. One was chemical treatment through tanks, and the passage of the effluent over a large area of land. The other was contact beds either single, double, or treble. The land they could not get: and contact beds with more than one contact involved pumping. If they discharged into the River Roding, which was a tidal river, at least double contact would be necessary to turn out the effluent sufficiently pure. Double contact again would involve pumping the whole of the sewage, because they could not get sufficient fall for more than one contact. They had therefore to discharge the sewage into the River Thames or take it out to sea. No doubt a chemically treated tank effluent comparatively clear would be of sufficiently good quality to be discharged into the tidal waters of the Thames. Taking all the circumstances into consideration, that was the scheme which his firm placed before the Ilford District Council, and the one which was eventually adopted.

At the present moment there was a great anxiety amongst engineers to turn out a better effluent than was wanted. If they had a sea outfall and a proper point of discharge at a considerable distance below low-water mark, where the sewage would be swept out to sea, and not brought on to the foreshore, it seemed to him that no treatment whatever was required for the sewage. And if they had a tidal river of large volume, then the chemical treatment of the effluent was all that was necessary. Again, they could grade up their treatment of sewage so that eventually they could come to the highest form of treatment with contact beds and land irrigation.

The sludge-pressing was going on at the present time. In the scheme which they placed before the District Council, there was a proposal to carry the unpressed sludge by means of a sludge-pipe down to the River Thames, and to pump it into a ship and take it out to sea, the same as was done with the London sludge at the present time. He thought that, in the near future, Ilford would see that it would be by far the cheaper method for them to adopt, than to continue with their sludge-pressing, especially when their population increased to something like 100,000.

Mr. R. F. Grantham expressed his appreciation of the value of the paper. It was always useful to learn what other people had done and the difficulties which they had met. In consequence of the flatness of the district, Mr. Hetherington must have had to consider well how the drains could be best laid and how the sewage should be carried away. It seemed, that, according to the paper, justice had scarcely been done to the treatment of the sewage by means of the bacteria beds and the septic tanks, but he thought that Mr. Taylor's explanation had made the matter clear. Of course it would have required a very large extent of contact beds, but at the same time it would have been very interesting if that process could have been carried out, even if there had been some extra cost for pumping, because one would like to know what the bacteria beds would really do on a very large scale. He had laid out several small ones, and so far they had answered very well. Some of them were built in accordance with the Local Government Board's rules, but three or four years ago he laid down contact-beds much below the dimensions required by the Board, and they had been working extremely well ever since. They, however, had to deal only with rather weak domestic sewage.

He quite agreed with what Mr. Taylor had said with regard to discharging sewage at a sea outfall, so long as they could get it below low water-mark, and at a point from which the current would carry it right away. But there were seaside places where sewage was discharged which might become a nuisance as years went on. There was one place he had in his mind, namely Bournemouth, though he did not think that there had been any complaint as yet. There were several sewage outfalls there, and, although they discharged far below low-water mark, there was no current which would take the sewage away from the bay. It would be interesting to see what became of that sewage as years went on.

Mr. C. F. Dawson said that he had been very much interested in the paper. There was, however, one point on which he should like Mr. Hetherington to give further explanation, namely, with regard to the construction of the manholes in waterlogged ground. He should like to know whether the cement mortar was poured in the cavity as grout, or whether the courses were flushed up in the ordinary way.

Mr. William H. Holttum said that the paper, which was very interesting, dealt with facts, and with a scheme which was well thought out under most difficult circumstances. As far as he could see by the map, there was one sewer which went from east to west, contrary to the trend of the river Thames, and in all probability against the lay of the country. That must have been a rather difficult sewer to put in. He referred to the one from Beacontree Heath, which ran south of, and parallel with, the existing high level sewer. Of course there was a flushing tank in use there. He wished to know whether the flushing tanks had always acted satisfactorily. Further, he should feel obliged if Mr. Hetherington would give the gradient of the particular sewer which he (Mr. Holttum) had referred to, and the gradients of all the sewers. The paper referred to gradients ranging from 1 in 500 to 1 in 5400 for the new effluent pipe only; if the gradients of the sewers were given, it would make the paper very interesting from a constructive point of view.

Mr. ARTHUR RIGG said that hitherto pumps for sewage works had been plunger pumps, which required to be constructed upon a different system from those pumps which were used for clean water. He observed that Mr. Hetherington used centrifugal pumps, for which, no doubt, he had good reasons. At the West Kent Sewage Board, Dartford, they had four settling tanks, emptied by chain pumps, which were worked by four of his (the speaker's) revolving hydraulic engines, and the whole arrangement of chain pumps and engines worked exceedingly well. The sludge was allowed to go into the tanks alongside the settling tanks, and in course of time it dried, and the farmers came and took it away, so there was not the same difficulty that Mr. Hetherington found in getting rid of his compressed cakes, for in the case of the West Kent sewage the farmers spread it over their land. Perhaps the sewage-cakes Mr. Hetherington had spoken about were not quite as rich as was supplied from the West Kent Sewage Board's tanks. Other pumps which he (Mr. Rigg) had made at different places had been of the plunger type, generally 20 inches in diameter, with 3-feet stroke. Some were worked by hydraulic engines, and some by cranks. Of course multiple valves were used, and they were of peculiar construction, for sewage required pumps altogether differently arranged from those which were used for clean water. Perhaps centrifugal pumps might have an advantage in the form of cheapness, but he could not see that they had any other advantage, but rather the reverse.

M. SYDNEY A. HOLLIS said that apparently the Roding Valley low-level sewer was laid in waterlogged ground, and he noticed that Hassel's double-joint pipes were used, surrounded by concrete. He believed that those pipes had proved to be water-tight in themselves. He should like to know whether the concrete was used to keep the pipes watertight, or on account of the depth of the sewer. If so, how would the cost of the pipes and the concrete compare with the cost of iron pipes? He should also like to know whether manholes built in the way described were invariably watertight.

The President said he wished to ask a question as to the construction of the contact-beds. The author said that he subsequently added six inches to the previous three inches of material. It would be interesting to know why the six inches was added. He had intended to ask the question which Mr. Dawson had asked with regard to the cement lining. He presumed that the lining was used on the invert of the manholes as well as the side. In the cement rendering of the tanks, Mr. Hetherington specified rendering in neat cement. He (the President) had generally understood that a mixture of cement and sand was better for that purpose than neat cement. Perhaps Mr. Hetherington would give his experience.

Mr. Hetherington, in replying upon the discussion, said, in answer to a question put by the President, that the most northerly of the sewers running from east to west was an old sewer, as also was the one running north and south from Barking Side. The only other old sewers were comparatively short lengths in the town itself. The ground on the south was only just beginning to be developed, and the development naturally spread along the line of the railway.

With regard to the conveyance of sewage from the Roding pumping station to the outfall works, there was no sewer shown on the map. There was, however, a high-level sewer running from close to the old pumping station to the outfall works, almost following the line of the existing low-level sewer, and into that the pumps discharged. The reason why that high-level sewer was not marked on the map was that it was at too shallow a depth to deal with any but a very small percentage of sewage of the district through which it passed, and consequently it was hardly fair to call it a high-level district

With regard to the pumps being fixed in two separate chambers at the new pumping stations, there had been several causes which had contributed to the arrangement. The depths of the two sewers were different, and if one chamber only had been built, it would have been necessary to pump the sewage of the lower one through an extra lift of four or five feet. The way in which the ground had developed brought the most northerly of the two sewers much more into use at first, and the pumps dealing with the most southern one were used only occasionally at present. The increase of population would in time alter that.

The question as to the use of the tanks as septic tanks had been answered by Mr. Taylor. As to the extra six inches which had been added to the bacteria beds, there was originally a six-inch fall from the distributing channel to each bed, and as the beds were being over-worked, the extra six inches was seized upon as a method for getting a little more coke.

The neat cement was used on the tanks, so that the surface might be as smooth as possible for the sake of easy cleaning. His experience was that neat cement gave the highest polish. He would not be exaggerating in saying that the surface which could be formed with neat cement was not materially rougher that a piece of writing paper.

A question had been asked about the manholes. There was no bonding between the two walls, the four-and-a-half-inch wall being outside, and the nine-inch wall inside. They were, built course by course together, with two to one cement mortar, and the space between them was filled in with the same mortar as each course was laid with. That was neither grout nor very stiff mortar, and it was very efficacious.

As to the gradients of the sewers, the ground fell in two directions; that was to say, in the valley of the River Roding as well as in the valley of the Thames. There was a fall from east to west, as well as from north to south, and the sewers were consequently laid in the direction of the fall of the ground. The sewers were in the majority of cases constructed with 15-inch pipes, and in those cases the controlling gradient was the same, namely, 1 in 750. The flattest gradient at which 15-inch pipe could be laid in order to get a self-cleansing velocity was 1 in 800. It was a coincidence that the controlling gradients were in most cases the same.

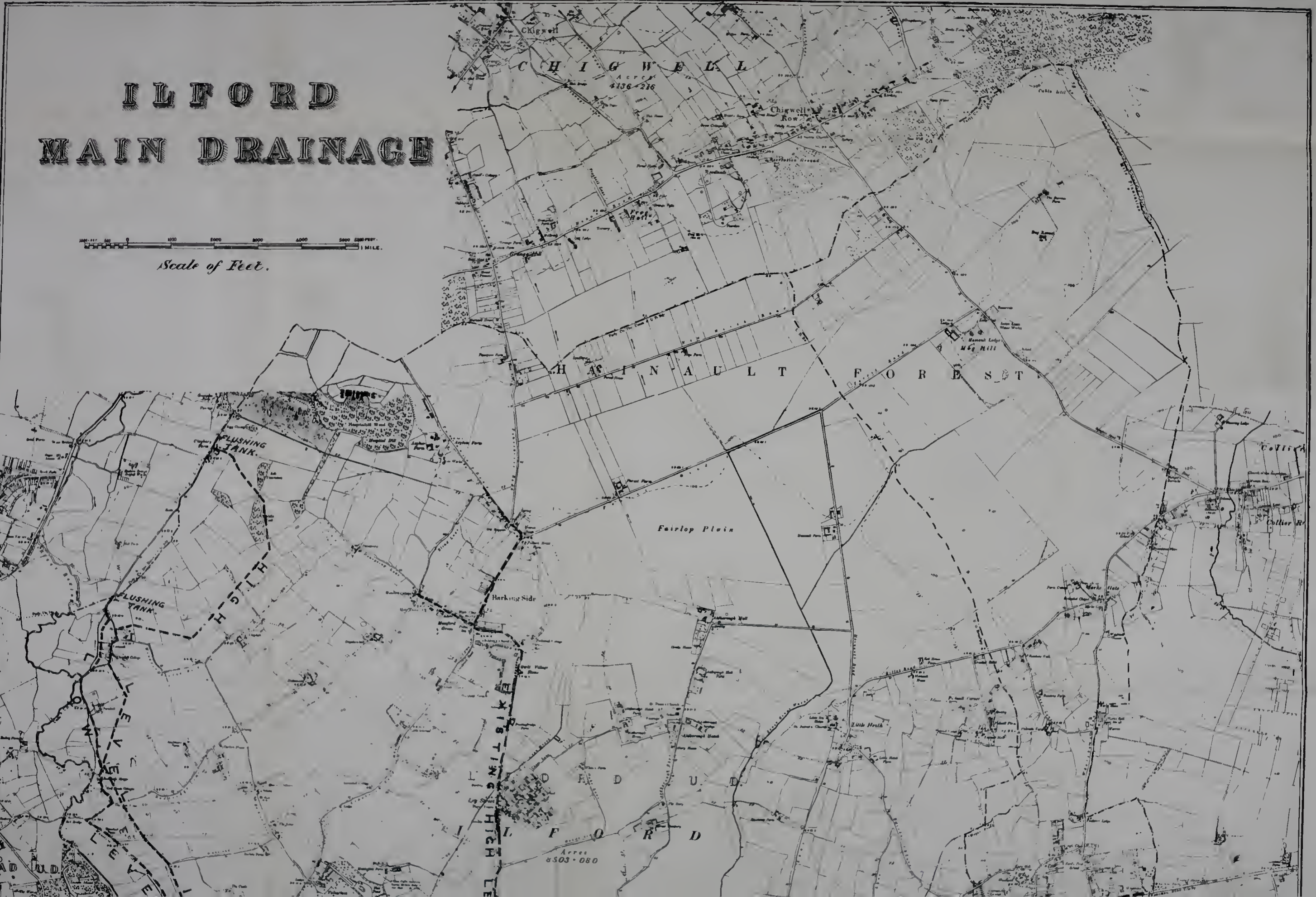
He was afraid that he could not give a very clear explanation about the use of the cake for manurial purposes. The cultivation in the district was entirely that of vegetables for the London market, and the farmers around would not take the cake even if it was delivered on to the ground for nothing.

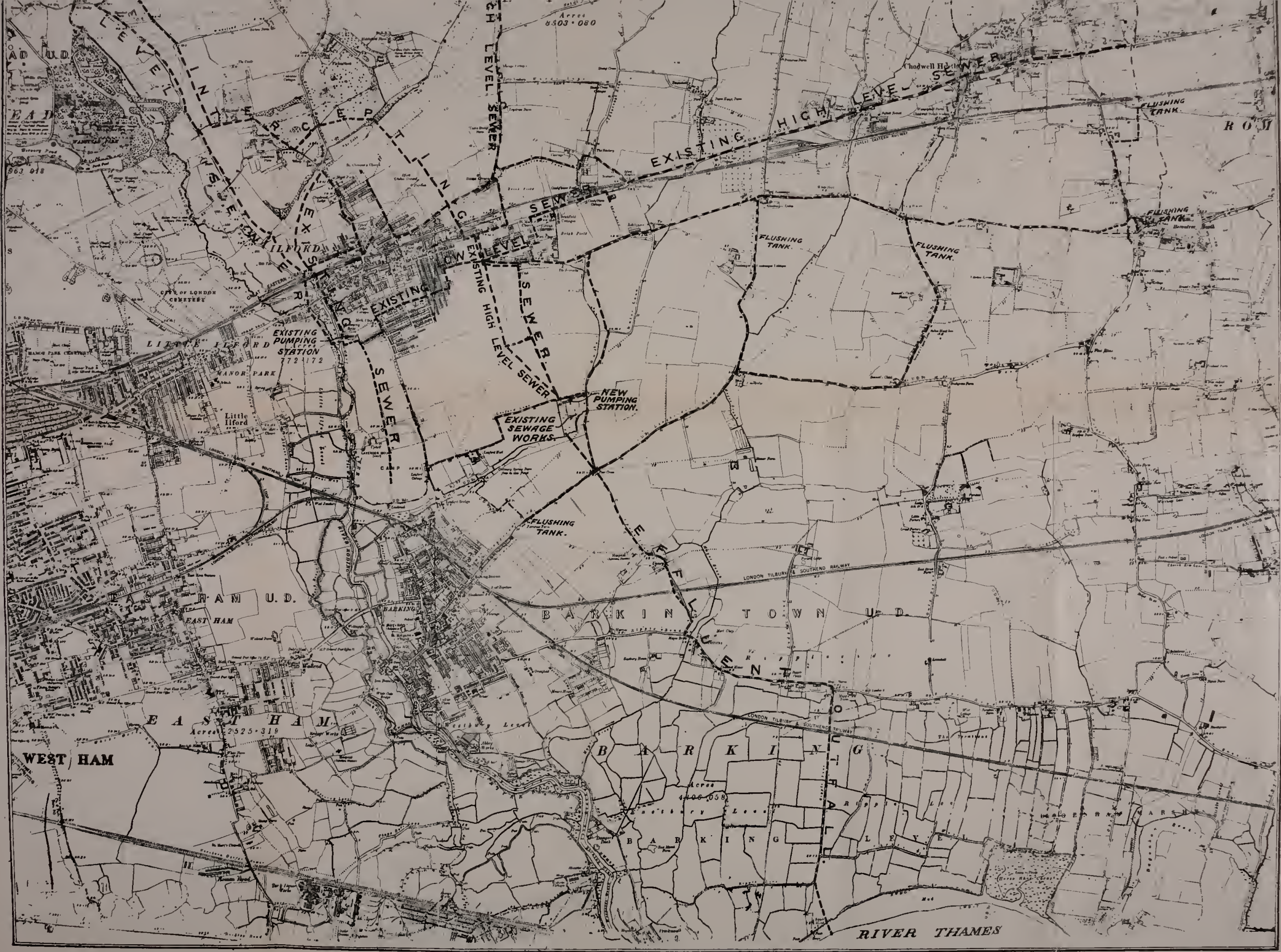
The chief reason for the use of the centrifugal pumps was that the works were cramped for room. The lift was very small, being under 30 feet, and the centrifugal pumps had proved very satisfactory.

Mr. Hollis had asked a question about the use of Hassal's double joint pipes with concrete around them. There was an accumulation of reasons which led to the use of the concrete.

The ground was very bad, and there was a lot of running sand, and the concrete was wanted to form a good foundation, and as a general strengthening to the pipes. The pipes themselves did not need the concrete to make them water-tight. He should not like to make a comparison off-hand between pipes with concrete around them and iron pipes, but he thought that the double-joint pipes with concrete would cost considerably less than iron.

ILFORD
MAIN DRAINAGE





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December 2nd, 1901.

CHARLES MASON, PRESIDENT, IN THE CHAIR.

THE SEWAGE QUESTION DURING THE LAST CENTURY.*

BY H. ALFRED ROECHLING.

INTRODUCTORY OBSERVATIONS.

THE century, which has just sunk into its grave—not without once more demonstrating, as it were, in its final struggle, that there is no such thing as unanimity of opinion, even when such unanimity is decreed from high places—has been very fertile of many theories, which, in a more or less pronounced degree, have influenced scientific investigations and their application to everyday life. These theories are so many in number and so manifold as regards species, that he whose duty it is to chronicle them all would indeed have a very difficult task. Even in the domain of natural science alone, which had been grossly neglected for other speculative considerations in previous centuries, and which, after claiming its own in the last, had marched rapidly onwards, the harvest of scientific thought is an exceedingly large one.

There might be mentioned as belonging to the front rank the atomic theory of Dalton, which has undergone marvellous developments never dreamt of by its originator; the theories of Liebig and Pasteur concerning fermentative and putrefactive changes, the former somewhat shortlived and replaced by Pasteur's ever-classical and memorable researches; and lastly, the theory of evolution as propounded by that "master of thought" Darwin, around which the strife of combating parties has raged very severe at times. But so great is the number of illustrious names, which have shed honour and light upon the path they have trod, that he who would faithfully record all the achievements attained, would have to fill many volumes.

However pleasant and instructive such a task might be, the author is debarred by limits of time, space, and patience from undertaking it to-night, nor can he sketch—were it even in ever so imperfect colours—the general progress of thought, which has made these theories possible, or trace their connecting links. He is bound to limit his remarks to one subject only, which may appear to many a very common-place one, viz. the theory and practice of sewage purification during the last century. After having reviewed the various stages through which this question has passed in that period, he hopes to be able to deal with one or two points in connection with it more particularly, with a view to elucidating them more fully, if that be possible.

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* The President's Gold Medal was awarded to the author for this paper.

Were he to attempt, however, to bring within the scope of his survey all the details of this most complex problem, he could not possibly finish his observations in one evening; and he is further satisfied that such a course would prove exceedingly tedious to his audience, and lastly, is not necessary either. To do so is subject matter for a lengthy and probably very dry text book, and all the author intends to do is to review the main principles underlying this apparently inexhaustible question. If, therefore, it may appear to some that important points have been omitted, or to others that the remarks are in places incoherent, the author would ask his hearers to bear in mind the limits of time and space under which he labours.

It has been said, an historical review is never out of place, and good may result therefrom; and the present time seemed especially suitable for such a purpose, as the waves of unbounded enthusiasm produced by the latest development of the sewage question appear to be subsiding, and to be giving place to calm and rational reasoning, such as was, for instance, the case at Glasgow at the recent Engineering Congress. Enthusiasm is always an important and most welcome factor in launching a new theory, but the danger is lest its waves rise too high, and in toppling over fall back upon their own exciting cause.

He who wishes to solve this difficult problem must deal with it in a thoroughly systematic manner and leave as little as possible to chance or accident. He must, in the first instance, endeavour to find out the agencies nature employs in the disintegration or mineralisation of organic waste matters, and the conditions under which they work; he must next try to adapt everyday operations on a large scale to the requirements of nature's agencies; and finally, he must keep these operations under his continued careful observation, for any offence against the laws of nature is sure to bring about disaster in the long run. He who goes about with his eyes shut on the edge of a deep precipice has only himself to blame, if after a while he finds himself at its bottom, landed there by the law of gravitation, and can thank his stars if he escapes with but few bruises. In like manner, courts that manager of sewage disposal works disaster, who pays no heed to Nature's eternal and unalterable laws.

But it is time now to leave these preliminary considerations and to deal with the subject proper.

BRIEF HISTORY OF THE SEWAGE QUESTION—THEORY AND PRACTICE—DURING THE LAST CENTURY.

Had the author's task been attempted one hundred years ago, it would have been considerably easier than to-night, for the then reader of a paper would have been in the happy position, that he could have exhausted the whole subject in a few words. For at that time instinct took the place of theory, and the practice of sewage purification was limited to one or two instances of sewage farming. Whether a working hypothesis existed to explain the process of sewage purification on land or not cannot now be ascertained, but the fact remains, that the sewage irrigation on the Craigentinny meadows at Edinburgh was so successful, that its employment has remained to the present day.

Leaving the dawn of the last century, it is evident from the records kept, that Cagniard de la Tour in France about the year 1825, and Schwann in Germany about the year 1836, expressed the opinion, that organised substances—micro-organisms—played some *rôle* in fermentative and putrefactive changes. This theory was hotly opposed by the great chemist Justus von Liebig, who, about the year 1845, maintained that these changes are brought about by the dead inert matter itself—by molecular movements in the same—and not by organised substances, the presence of which, in fermenting or putrefying substances, was purely accidental. As was to be expected from the authoritative position of its exponent, Liebig's theory was shared by many, and the strife that commenced around it was fought with great bitterness. But the bulwark of old ideas, which were gradually but surely being supplanted by new ones, could not hold out for ever against combined attacks, however stoutly it was defended by its designer, and its final collapse came about the year 1860, when a young Frenchman, Pasteur, established beyond a doubt by his classical researches, that fermentation and putrefaction were, in the first instance, due to living organisms and not to dead matter. Pasteur further showed that living organisms were also the cause of some and probably of all zymotic diseases.

But unfortunately Pasteur's methods of biological examination left much to be desired, and it was not till some twenty-two years later, when Robert Koch of Berlin published his new methods in 1882, that real progress could be made with these questions. It has been stated, that Koch's new methods were the signal of raising the floodgates of biological (bacteriological) research throughout the world; and certain it is that its flood waters, pent up until then, inundated for a considerable time afterwards other branches of scientific research to such an extent as to practically drown their individual life. During these twenty-two years (1860–1882) chemists, who studied the nature of the impurities contained in sewage, had to proceed by indirect methods. They had no means of ascertaining by direct biological experiment the number and character of the micro-organisms contained in sewage: all they could do, was to determine the dangerous nature of the sewage, by the amount and origin of organic matter it contained, which would probably act as food to the germs; and the greater this amount was, the greater it was argued might be the number of germs it contained, and the more dangerous its character.

This was the condition of things at the time the second Rivers Pollution Commission carried out its investigations, which in many respects, and rightly too, are still considered standard investigations. It cannot be surprising, therefore, that, being without proper means of biological investigation, this Commission came to the conclusion, that the processes taking place in sewage purification were of a mechanical and chemical nature.

Probably the first to apply, in a general way, Pasteur's theories to the problem of self-purification of sewage was Alexander Müller, who made his experiments in 1869 and published them in 1873. It would be going much too far to deal here minutely with all the other experiments that have been conducted since then, either with a view to study special phases of this question or its general aspect. It must, therefore suffice to mention the names of some of the more representative experimenters, such as Schloesing, Müntz, Hatton, Warrington, Sorby, Winogradsky, P. Frankland, Dupré, F. Emich and Dibdin. All these investigators contributed their quota, and strengthened the belief that in the decomposition of sewage, living organisms play a very important part. But that set of researches which has more than any other confirmed it and put it upon a sound and substantial basis are the investigations of the Massachusetts State Board of Health, which were commenced in November 1887, and are still being continued.

Since 1895, a number of further experiments have been made, which will be dealt with when the practical side of the sewage question is under consideration; but, speaking generally, they have not materially increased our knowledge of the processes taking place in sewage purification. Summarising the remarks on the theoretical aspect of this question, it may be said, that as to the agencies at work, we know now, they are of a mechanical, chemical and biological nature; but as to the processes brought about by these agencies, we know very little beyond the initial and terminal stages.

In his very interesting and instructive book on "Sewage and the Bacterial Purification of Sewage," which ought to be in the possession of every student of this question, Dr. S. Rideal has lately made an ingenious attempt to divide the changes during which organic matter is converted into mineral, into four distinct stages. But it remains yet to be seen, whether his intermediate two stages are not again subject to a good deal of further subdivision; and at the best any such division must, at the present time, be more in the nature of a shrewd guess than based on actual incontrovertible facts. It has also been maintained, and that too in well informed quarters, that, in the self-purification of sewage, chemical agencies played no important part, and that all chemical changes were brought about by biological agencies. On the other hand, it has been asserted at Berlin, that the chemical changes produced in this process were only in a very small measure due to micro-organisms. In the author's opinion the truth lies probably between these two extremes; and in support of other agencies besides biological ones, he would quote from a paper recently published by Dr. Dunbar, of Hamburg.

This gentleman has made a large number of experiments, which appear to have been conducted with great care and skill; and, summing up his results on one branch of his inquiries, he says: "From the results of our experiments it cannot be doubted, that the reduction in the consumption of oxygen, which is very noticeable in the effluents from the oxidation (contact) beds, the retention of the dissolved organic matters in these beds, and the removal of smell and putrescibility are in a great measure due to absorbing powers, i.e. to chemico-physical precipitation of these substances out of the liquid, and retention on the surfaces of the material, with which the oxidation bed is filled."

Referring to the question whether the consumption of oxygen by the bed and the production of carbonic acid is to be attributed to the action of micro-organisms, Dr. Dunbar observes: "I hesitate to draw definite conclusions concerning these processes. It does not appear to be impossible, that the liberation of carbonic acid may take place in an indirect way, and is not solely to be considered as a measure of gaseous changes brought about by micro-organisms. The relative high consumption of oxygen, which is noticeable at the commencement in sterilised oxidation beds, appears also to indicate that the micro-organisms do not withdraw the oxygen direct from the atmospheric air: that, on the contrary, the latter is fixed by absorption and is withdrawn from the absorbing substances in an indirect manner by the micro-organisms. It is possible that through the action of micro-organisms a certain oxygen deficit is created, which is balanced on the access of atmospheric air."

After having followed the theoretical views on sewage purification right through the century, it becomes necessary now to study its practice during that period. At its commencement the only known method of sewage treatment, as has already been stated, was land irrigation. Then about the middle of the century chemistry seems to have taken the matter in hand and tried to make a lucrative business out of it. It is on record, however, that it did not succeed in this attempt, and the financial loss, which this endeavour has caused, is a dismal subject to investigate.

The emphatic verdicts of the first Sewage Commission of 1857, the first and second Rivers Pollution Commission, and, indeed, of all other authoritative investigations, was in favour of land treatment; and it cannot, therefore, be surprising to find, that the Local Government Board insisted, save in exceptional cases, that "any scheme of sewage disposal, for which money is to be borrowed with their sanction, should provide for the application of the sewage or effluent to an adequate area of suitable land, before it is discharged into a stream." Indeed, had this body taken any different view and neglected the findings of practically all authoritative inquiries, it would have been singularly deficient in the discharge of its duties to the ratepayers of this country.

But the best of land cannot do its work, if by systematic neglect and ignorance, the essential conditions for successful purification are year after year violated; and the great pity is, that the Local Government Board, after deciding in favour of land treatment, did not systematically superintend this operation. It may not have had the power, but it is quite evident, that had it done so, things would not have drifted from bad to worse, until local authorities, driven to despair by the apparent failure of land, and not discerning the right cause, refused altogether to be ruled by what seemed to them a very unfair and absurd restriction.

It was at this time that Mr. Dibdin, who, on behalf of the London County Council, had been carrying out a set of most valuable experiments, came forward with his application of well known theories to sewage operations on a practical scale. As the author pointed out at the time, Mr. Dibdin's experiments proved beyond a doubt that the application of sewage to suitable land was right in principle, and that the failures were brought about by the non-observance of the rules laid down by this gentleman—that in fact sewage irrigation was the only natural method of sewage purification, and that all the other methods were artificial. He described land treatment as the natural self-purification of sewage, and the oxidation or contact bed system as the artificial self-purification of sewage.

But the current of public opinion had very strongly set against sewage farms, and nothing but the contact bed treatment would do. A large number of experimental plants on this system were erected all over the country, and the waves of enthusiasm seemed at one time to engulf even the Local Government Board itself with its antiquated notions, until Parliament came to the rescue, and on May 7, 1898, appointed a new Royal Commission to study the question of sewage purification.

It should not be forgotten, that, contemporaneous with Mr. Dibdin, Mr. Scott-Moncrieff and Mr. Cameron had also experimented with sewage and evolved quite independently their own biological methods of treatment. It was hoped by the admirers of the new systems, that this Royal Commission would make a clean sweep of the land treatment, but had it done so, it would, in the author's opinion, have stultified itself; for how could it possibly find against sewage irrigation, when commission after commission before had given an unmistakable verdict in its favour. The only possible way in which the Commission could undertake the task entrusted to it, was by commencing where previous inquiries had left off. In this sense then must the conclusions, at which the commissioners have arrived in their interim report, be considered.

They divide evidently all sewage treatments into two main classes, viz., natural and artificial, and whilst putting land only into the first class, they call all other modes of treatment artificial. As to land, they apparently take it for granted, that the application of sewage to suitable land is a proper method of sewage treatment, and they observe: "We doubt if any land is entirely useless." They are, however, forced to conclude, that peat and stiff clay lands are generally unsuitable for the purification of sewage. As to peat, nobody would probably be prepared to differ from their conclusion, but when making the statement as to clay soils, they must have known, that the sewage farms at South Norwood, Wimbledon, Warwick and Leicester, which are all on clay land—the Leicester boulder clay is of a very dense nature—have given very fair results in the past.

Next, the commissioners deal with the artificial processes; and here they are of opinion that it is practicable to produce by artificial processes alone, either from sewage or from certain mixtures of sewage and trade refuse, effluents, which might be discharged into a stream without fear of creating a nuisance, and that, in consequence, the Local Government Board would be justified in modifying under proper safeguards the present rule as regards the application of sewage to land. What these artificial processes are is not specifically stated, but it is clear, that the conclusions of the commissioners do not refer to the sole application of chemical methods, but to one or other form of biological treatment. In the case of artificial treatments they consider it necessary, that every case should be treated on its own merits.

Concerning the bacteriological qualities of effluents, the commissioners find, "that, while in the case of effluents from land of a kind suitable for the purification of sewage, there are fewer micro-organisms than in the effluents from most artificial processes, yet both classes of effluents usually contain large numbers of organisms, many of which appear to be of intestinal derivation, and some of which are of a kind liable, under certain circumstances at least, to give rise to disease." The commissioners do not give particulars; but later on it will be pointed out, that their conclusions are not borne out by the published results from sewage farms, so far as they are available.

Concerning rivers pollution, the commissioners are of opinion, that the simplest possible means should be provided for adequately protecting all our rivers, and that a separate commission or a new department of the Local Government Board should be formed, which shall be a supreme rivers authority dealing with matters relating to rivers and their purification, and which, when appealed to, shall have power to take action in cases where the local authorities have failed to do so.

Summing up the remarks on the practice of sewage treatment, it comes to this, that at the end of the century, land treatment has been re-established by the Commission now sitting, in its position as the first and only natural method of sewage treatment, and that beside it certain artificial (biological) methods have been recognised as being, under proper safeguards, admissible for the purification of sewage without land.

Self-Purifying Powers of Soil; Natural Self-Purification of Sewage.

It may not be out of place now to make a few observations on the self-purifying powers of soil, and it should be stated at the outset, that these powers vary considerably with the character of the soil and other local conditions. Hence, observations in one locality cannot be applied to others without making full allowance for the differences. Water, which has been poured upon the ground, will disappear sooner or later in the pores of the soil, and is here to a certain extent retained. This property has been called the retentive power of the soil, and is due to adhesion and capillary attraction.

Had the water contained polluting substances, such as characterise town sewage, these substances would likewise have been retained by the soil, and that in the following manner. The suspended matters, including the germs and other micro-organic life would have been strained out by it in a purely mechanical manner, the soil acting like a fine screen, and the dissolved matters, after removal out of the liquid, would have been absorbed by it—a chemico-physical process attributed to the surface attraction of its particles or grains. That this attractive force is pretty considerable will be at once apparent when it is stated, that 1 cubic yard of coarse gravel may contain about 140,000 grains with a combined surface of 50 square yards, and 1 cubic yard of fine sand 40,000,000 grains with a combined surface of 9200 square yards, which is a little under two acres.

Besides the properties of the soil just enumerated, it may not be without interest to state that it is also capable of retaining colours (i.e. to decolorise), of absorbing gases (hence its deodorising effect), and to retain poisons such as strychnine, nicotine, coniine, etc. But there are limits to the retentive powers of soil, and when these have been reached and the flow of liquid pollution still continues, the excess liquid passes down into deeper layers, during which process it is presumably likewise subjected to a purifying process. The rate of this downward movement will depend on local conditions, but appears as a rule to be slow.

The depth to which polluting substances can penetrate into soil will probably differ in each case, but the following factors may be said to influence it, viz. the velocity of the downward flow, the nature and degree of the polluting liquid, and the character of the soil. Taking the micro-organic life in soil as an indication of the presence of polluting substances, it may be said that a depth of six feet is, as a rule, the limit of favourable conditions for its development, and although micro-organisms have been found at greater depth, their presence there is to be explained by emigration from higher layers and not by actual growth at these depths.

After the polluting substances have thus been stored in the soil, they undergo in its pores—and that probably chiefly during periods of rest—a process of disintegration or decomposition, which does not terminate until the whole of the organic matters have been converted into stable mineral forms. This process—the retention, absorption and decomposition of impurities—has been called the "self-purifying power" of soil. When this process of combustion is completed, the converted substances either act as food for the plant life, or they are removed out of the subsoil by the underground water or air.

The whole of these intricate changes have been likened to the process of digestion, and if the digestive powers of a soil are overtaxed, signs of sickness may be noticed, which increase until, in sewage phraseology, the whole becomes "sewage-sick." In this state the land remains until the flow of the polluting liquid is stopped, when after a period of rest—recreative period—its digestive powers return and begin to do their work afresh. When the soil of a sewage farm has got into this state, owing to having received heavy doses of sewage, the application of lime has proved very beneficial by accelerating the process of nitrification, and in this respect interesting experiments have been made on the Berlin sewage farms. The action of the lime is said to be a two-fold one:

1. It quickly attacks and splits up all organic matters, and after doing so accelerates their decomposition in the soil and their being taken up by plants.

2. It neutralises the excess of acid in the soil and causes the latter to part with its carbonic acid.

The process of decomposition proceeds as a rule at a much quicker rate in the layers near the surface of the land than in those lower down.

An important point for consideration here is the mechanical state of the polluting substances, as, with these in a finely divided condition, the work of the soil is considerably lightened. Hence in sewage farming it will always be an advantage either to hold the suspended matters back in subsidence tanks or to break them up, such as is probably done in their passage through the openings of a strainer or the valves of a pumping engine. In this process of mineralisation a number of factors play an important part, such as the amount of atmospheric air contained in soil and its facilities for a rapid exchange of air, warmth and moisture, the two latter of which are always contained in sewage, and for effecting the first on sewage farms a systematic underdrainage is of primary importance.

Nothing has been said, so far, as to the agencies which bring about the process of decomposition or putrefaction, but it is now generally held, that these are of a biological nature (bacteria and protozoa). To what extent other agencies assist this biochemical process is at the present time not cleared up, but some observers seem to think that the assistance of mechanical and chemical agencies is by no means impossible. Fischer, in his interesting book "The Structure and Functions of Bacteria," observes (page 99): "The decomposition of dead animal bodies, of vegetable tissues, or of substances like stable manure, is far from being a simple putrefactive process. Side by side with the disintegration of nitrogenous bodies there are going on a number of fermentative changes by which non-nitrogenous compounds are being broken up, besides nitrification and other bio-chemical processes. For this reason it is always difficult and often impossible to determine the respective parts played by the different species of bacteria." . . . . "The phenomena of putrefaction are so complicated, that we do not know all of the compounds that arise during the process." . . . . "Very careful chemical investigations on pure cultures will be necessary before the chaos of phenomena presented by putrefactive bacteria can be arranged in something like order."

Fischer distinguishes five or rather six groups in this process of putrefaction:

"1. Albumoses and peptones: soluble diffusible bodies closely resembling albumen. They are produced by the action on albumen of bacterial enzymes similar to the enzymes (pepsin and pancreatin) which give rise to peptones in the digestive tract of man.

"2. Aromatic compounds: among others indol and skatol which give the characteristic odour to human excrement; also some non-nitrogenous substance such as phenol, phenylacetic acid, and phenyl-propionic acid.

"3. Amido compounds, all nitrogenous: leucin, tyrosin, aspartic acid, glycocol.

"4. Fatty and aromatic acids, all non-nitrogenous, and therefore having no part in the circulation of nitrogen: acetic, butyric, succinic, and valerianic acids.

"5. Inorganic end-products of putrefaction: free nitrogen, ammonia, free hydrogen, methane, carbonic acid, methylmercaptan, sulphuretted hydrogen. It is probable also, but not certain, that phosphoretted hydrogen is formed and is oxidised at once by the free oxygen of the atmosphere.

"Most of the substances," continues Fischer, "are formed also by the chemical decomposition of proteids, but there is a sixth group which may be termed specific putrefactive products. These are the so-called ptomaines or putrefactive alkaloids."

Some of these are either not poisonous or only poisonous in large doses, whilst others are highly poisonous, toxines.

It will not be necessary here to deal further with the substances produced in this bio-chemical process beyond making one or two observations on the fate, on sewage farms, of these highly poisonous toxines produced by bacteria. These substances fortunately are very unstable, and the experiments by Falk and others seem further to indicate, that soil is capable of retaining them and of rendering them harmless. At any rate there is no well-authenticated case on record of these substances having wrought mischief on sewage farms.

Another very interesting point in connection with the germs contained in sewage is the ultimate fate of pathogenic germs on sewage farms, and a few observations concerning it may not be out of place.

It is well known, that at one time of his career the late M. Pasteur considered that the wholesale spreading of disease germs on sewage farms, might prove highly injurious to the public health of the neighbourhood. As he himself admitted, he based his fears on purely theoretical considerations, and opposed, for this reason, the extension of the sewage farms in the neighbourhood of Paris. But when, later on, he was made acquainted with the results observed on the Berlin farms, he modified his views and ceased to oppose the extension of the Paris farms. Indeed, search as he might, the author has not been able to discover one single instance, where a sewage farm has acted as the focus of a local outbreak. On the contrary, during one or two small epidemics of typhoid fever in Berlin, no case of this complaint has been observed on the sewage farms of that city.

But it has been maintained, and with considerable persistency, that pathogenic germs might pass through the soil into the effluent drains and thence into the streams, where their presence might cause disastrous results. There is, however, no case on record, where such a thing has actually occurred: indeed, very painstaking investigations on the Berlin farms have led to negative results.

Another sewage farm, that of Freiburg in Baden, has likewise been made the subject of careful and long-continued investigation by Dr. Korn, who for the twelve months ending August 1897 made no less than 165 elaborate chemical and bacteriological examinations. Summing up his observations on the presence of bacteria in the effluents from subsoil drains, he remarks :—

"Apart from the few exceptional cases of high numbers, generally speaking my experiments show that the number of germs in the subsoil drain effluents is relatively small, and even omitting those experiments, in which a dilution with subsoil water must have taken place, the number of micro-organisms is still so small, that the effects of filtration through soil are clearly perceptible. In addition to this—and this is of considerable importance in forming a judgment—it must be borne in mind, that the bacteria in sewage are principally derived from the intestines, whereas in the subsoil drain effluents, the inhabitants of the intestines are either not present at all, or only in very small numbers compared with the number of soil and water bacteria, which are always present. Out of 165 examinations I only succeeded in 18 cases in proving the presence of *bacterium coli*."

Although the present is perhaps not quite the right occasion to deal with the matter, it may be convenient for reference to state here, that *bacterium coli* can no longer be looked upon as a typical inhabitant of the human intestines after the very elaborate investigations carried out by Dr. Weissenfels, who arrived at the following conclusions:—

1. The so-called *bacterium coli* can be cultivated from almost every kind of water and its presence can be demonstrated in nearly every case, provided that a sufficient volume of water is utilised.

2. It is not possible by the result of the experiments upon animals to decide whether the *bacterium coli* was cultivated from a pure or infected water, and the discovery of a virulent *bacterium coli* in any sample of water cannot, therefore, be regarded as a criterion that such water has been polluted with fæcal bacteria.

After these remarks it seems quite possible, that the *bacterium coli* discovered in 18 cases by Dr. Korn in the Freiburg effluents was not derived from sewage at all but from the ordinary subsoil water of the land. It is quite clear, therefore, that neither theoretical investigations, as available up to now, nor practical results, support the theory that pathogenic germs may do mischief on sewage farms, and one is bound to conclude, that this possibility, after systematic treatment on land, is an exceedingly remote one.

It may not be without interest here to sketch out how the bacterial activity proceeds in soils. This sketch makes no claim to literal accuracy in every detail, but must be understood to be based on observations, enlarged and supplemented in places by speculative considerations.

It must be assumed, that the bacterial flora of decomposing substances is subject to continuous changes, which last during the long process of the conversion from the organic into the inorganic state. In the same a number of substances are produced, which are of a highly poisonous nature. The number of germs is greatest on and near the surface and gradually decreases until at last a depth is reached, depending on circumstances, in which the soil is perfectly sterile The ærobes live near the surface and carry on their work in this region, whereas the anærobes are the inhabitants of deeper layers.

The picture of the cycle of bacterial activity in the upper layers of the soil during the various seasons of the year is probably the following. In winter, especially during that period when frost and ice bind the earth, bacterial life is apparently at its lowest ebb, and may in some very cold climates come to a standstill altogether, when bacteria may be said to hold their vegetative winter sleep. With the return of life and the awakening of nature in spring—especially with the approach of higher temperatures and the formation of moisture—bacterial activity once more makes itself felt all around. During the summer months it is exposed to some injurious influences such as the heating and drying up of the upper layers of the soil, but, still gradually increasing, bacteria reach the climax of their activity during the autumnal rains, to remain in this state until with the advent of the cold season their activity gradually declines again.

In the lower layers of the soil, down to 3 feet and 6 feet, bacteria are more protected against the injurious influences of the atmosphere, sunlight and drying up, but the want of oxygen, together with the greater difficulty of removing such products as carbonic acid, has an injurious influence. As the temperature in these layers is considerably more uniform, it may be inferred that the bacterial activity is there of a more uniform kind, less influenced by sudden changes, probably also less intense, but without pronounced periods of rest. In depths greater than 6 feet bacteria probably perish very quickly owing to unfavourable conditions. On sewage farms bacterial activity is without doubt greatly modified and proceeds all the year round at a more uniform rate than on ordinary land, as the sewage always contains the necessary warmth and moisture so beneficial for their life's work.

Concerning the depth of soil necessary for the successful retention, absorption and decomposition of sewage, no general rule can be laid down, as this will depend on a variety of determining factors, amongst which may be mentioned: the character and thickness of the top soil (humus); the nature of the cultivation of the top soil, the character of the subsoil (the amount of air it contains and the facilities it affords for a quick exchange of air), the surface slopes of the land, and the level of the subsoil water (thickness of the zone of evaporation and of the passage and capillary zones). On some farms a thickness of 3 feet has proved sufficient, and whilst with the exception of peat—owing probably to an excess of moisture—no soil is practically wholly inefficient, a loamy sand subsoil has in many cases given very satisfactory results.

When engaged in laying out the Leicester sewage farm in 1888, the author found his powers of locomotion over the land greatly impeded during the wet seasons by the inordinate amount of clay that adhered to his boots, but when engaged again for some considerable time on the land during last winter, this unpleasant peculiarity had completely disappeared even on land that had recently been sewaged. Through the action of the sewage the very dense clay had been disintegrated and become so friable, that, when trod upon, it crumbled to pieces. The colour of the soil had been changed from a yellowish brown to a greyish black, and altogether the land had been greatly improved by the application of the sewage.

The Artificial Self-Purification of Sewage in Septic and other Tanks followed by Treatment in Oxidation Beds.

It now becomes necessary to pass from the natural self-purification of sewage, or from the self-purification of sewage in the only natural medium, to the artificial self-purification of sewage, or to the self-purification of sewage in artificial media. And here it shall be admitted at the outset, that apart from the sludge difficulty, which has been reduced but not altogether removed, this self-purification either in open or closed septic tanks, followed by treatment in oxidation beds, has, so far as the chemical purity of the effluent is concerned, given very fair and encouraging results. Taking, for instance, the London experimental results, the following appears in the Annual Report of the Main Drainage Committee for the year ending March 31, 1901: "As regards the chemical character of the filtrate it may be stated that the suspended matters in the crude sewage are, practically, entirely removed as a result of the biological treatment, while a reduction of at least 50 per cent. takes place in the amount of the dissolved oxidisable and putrescible organic matter."

Similar and probably still more favourable results have been obtained elsewhere, but—and this is a very important point—they have all been achieved with experimental plant only; and who, well acquainted with the management of sewage disposal works, would believe that these experimental results could be obtained in everyday operations on a large scale? It is more than probable, therefore, that, in practical working, the average percentage purification figure will sink to 50 and below. At any rate, this has been the experience in the past with other modes of treatment.

The causes of this deterioration of theoretical results in practical working are not difficult to define. In experimental work the experimenter has the whole of the conditions better under his control than in large sewage disposal works; he can further bestow more care upon his plant than is possible in large scale operations. The observers are all trained men, whereas in sewage works the care of many details is left entirely in the hands of totally inexperienced men, who have no notion of the importance of the task entrusted to them; and, finally, as in many other things human, "familiarity breeds contempt," by which is understood, that after a while even the best intentions formed at the commencement gradually fade away into oblivion and leave a certain callousness and indifference behind, which feelings are by no means very safe guides to success.

It may be such causes as these, which have led in one or two instances to notable failures with artificial self-purification plants. 'Truth,' in its own graphic way, reported on June 6, 1901, the failure of such an installation at Aldershot, and from abroad comes the news, that, strange to say, likewise in a large military encampment of the Bavarian army on the Lechfeld near Augsburg, an open septic tank installation so completely broke down, that it had to be abandoned altogether. The population of this camp is about 7000, and the purification plant consisted of catch-pit, settling tank, open septic tank, primary oxidation bed with artificial ventilation, secondary oxidation bed, and four final oxidation beds. The report contains the following passage: "It is to be regretted, that it soon became evident, that the results obtained from this installation were in every respect unsatisfactory. It was especially noticed that even when, temporarily, a considerable reduction of putrescible substances was effected, no guarantee existed as to a perceptible reduction of bacteria." . . . . . "This compelled the military authorities, especially as in addition the frequent cleansing and renovation of the oxidation beds involved a very considerable expenditure, to abandon the works altogether."

In considering proposed works of this kind, it is important, therefore, to bear in mind this possible deterioration of theoretical results in practical working through one cause or another. There can be no doubt, that in artificial self-purification, carelessness and neglect will work mischief at a much quicker rate than on sewage farms with a fair area. Works for the artificial self-purification of sewage are delicate pieces of mechanism, capable, under intelligent supervision, to do much good work, but also with a high potentiality for mischief.

The idea formerly frequently expressed, that the oxidation beds would go on doing their work for ever without cleansing and renovating is now exploded; and during the discussion on Colonel Jones' and Mr. Campbell's interesting papers at the Glasgow Engineering Congress, it was stated by one speaker, that the cleansing of the beds in his case would cost 250*l.* per annum.

So much for the chemical purity of the effluent, but concerning its bacterial purity, the author has always been of opinion that it would differ but little from raw sewage. That this view has been borne out by the actual results obtained so far, is well known, and in addition to the case of the Lechfeld already quoted, two further instances may be referred to.

Dr. Houston, who, on behalf of the London County Council, has very carefully dealt with the bacteriological side of the experiments carried out since February 8, 1898, sums up his third report, issued on May 24, 1900, as follows: "In view of these results, only one conclusion seems possible, namely, that, however satisfactory the process may be from the chemical and practical point of view, the effluents from the bacterial beds cannot be reasonably assumed to be more safe in their possible relation to disease than raw sewage slightly diluted, but otherwise unaltered in its bacterial composition."

Interesting in this respect are the remarks which occur in the Annual Report of the Main Drainage Committee of the London County Council for the year ending March 31, 1901: "Pending further consideration of the whole matter, we are unable to advise the Council to adopt any particular scheme for the bacterial treatment of sewage, and the question whether the benefits to be derived therefrom would justify the Council in incurring the very heavy expenditure required to establish such a system, estimated at considerably over two millions, is still engaging our attention."

The other case, in which similar conclusions were come to, is reported from Charlottenburg, a small town near Berlin. The report, which was drawn up by a commission consisting of six well known experts, is summed up as follows: "The bacteriological results, which agree well with each other, prove that the material of the oxidation beds is of little importance for the bacteriological effect. The relatively greatest reduction of all kinds of bacteria is noticeable after two hours' stay in the beds, so that this period is practically to be preferred to a period of twenty-four hours in the beds. This reduction is, however, never so great that, epidemiologically, it could be considered of any real importance."

It has been maintained that it is not necessary to trouble about saprophytic and pathogenic germs in the effluents from artificial self-purification works, that it is quite sufficient to remove the suspended and dissolved dead organic substances and to let the organised substances take care of themselves. Such a position seems to say the least, very illogical, for surely if it is necessary at all to purify sewage, it is necessary to take out its most dangerous constituents, and whilst in a few cases the local conditions may not be favourable for further mischief by pathogenic germs, their wholesale admission into all our streams is an eventuality that the legislature cannot contemplate without the very gravest concern. Would not an action lie against an authority, which has in this way caused an outbreak of typhoid fever lower down the stream?

Another point to be considered here is the effect upon the vegetation in the stream of the admission in large doses of substances capable of being taken up by plant life, which are contained in the effluents from artificial self-purification works. For it will not be contended, that the manurial elements of sewage are in any way utilised in the artificial self-purification of sewage. They are converted, so it is maintained, by this process into such forms as to be readily available for plant life.

Is it not possible that these substances may encourage such a luxuriant vegetation in the stream, as to practically obstruct its flow and cover the whole bed? Floods and other causes might then destroy portions of it which, floating down the river in a dead and decomposing condition, may give rise to objectionable emanations.

Dr. J. Koenig, in his book "The Pollution of Rivers," makes the following observations: "It further remains to be seen, what becomes of the non-volatile products of oxidation such as nitric and sulphuric acid, which, though fixed by lime and magnesia, may be occasionally harmless; in most cases, however, must bring about with other washed-out substances a pollution of subsoil and river water, especially encouraging in the latter an abnormal growth of algæ." Such a state of things, would, however, be most undesirable, and could not be tolerated by the legislature.

COMBINATION OF NATURAL AND ARTIFICIAL METHODS OF SELF-PURIFICATION OF SEWAGE.

It now only remains to make a few further observations on the two methods of self-purification before bringing this paper to a close.

The difficulties, to which attention has been drawn in the foregoing observations on the artificial self-purification of sewage, seem to point, as it were of themselves, in the direction of supplementing it by land treatment with a view to satisfying all reasonable requirements. In that case, it may safely be assumed that there would be a considerable reduction of germs in the final effluent, the passage of pathogenic bacteria into the same would be rendered almost impossible, and the manurial elements of the effluent could be utilised, if not wholly, at any rate to a very large extent. Such an additional treatment would also act as a safety-valve in case anything went wrong with the artificial plant, it would retain and render harmless mineral poisons contained in sewage which would otherwise find their way into the streams and then destroy all animal life, and might further be of the greatest benefit during periods of severe frost, when the material of the oxidation beds, during rest, has become incapable of doing its work.

What area of land would be required for this purpose remains to be ascertained in each individual case, as the information available up to now is not sufficient to answer this question. But it may be concluded that it would be materially less than the area required for a sewage farm pure and simple.

On the other hand, where an existing sewage farm has shown clear signs of overwork, and where a manuring with lime at the rate of from 1 to 1½ ton per acre has not had the desired effect, it might be of considerable advantage to submit the sewage to a partial bacterial treatment before application to land, so as to lighten the work of the latter. Such a course has been adopted at Birmingham for the last two years, where the open septic tank is said to have given very satisfactory results, and is now suggested for Leicester, but in this case the closed septic tank does not appear to have given good results in the experimental treatment. It will be interesting to note whether in actual working the experimental results will be confirmed.

CONCLUDING OBSERVATIONS.

Whatever may be the methods of the future, the author is fully satisfied that none will succeed unless the supervision of sewage disposal plant is radically altered. At present it is only too common to find them in the hands of men who have insufficient knowledge, and probably less experience, to superintend such complicated operations. That sewage purification is a most complex problem will not be denied by anyone acquainted with it; and to supplant all manual labour by automatic machinery will, in the author's opinion, not lead to the desired results in the long run, unless the automatic machinery is also provided with brains. Who would think of entrusting the complicated machinery of one of our passenger express locomotives to a totally inexperienced driver? Not until the driver has gone through a regular course of training and demonstrated his fitness for the post is he entrusted with so important a piece of mechanism, and why should this course not be followed in the case of a sewage purification plant?

A special department of sewage purification might be created in connection with one of our agricultural colleges, or some other means of educating our future sewage disposal managers might be found. This question is undoubtedly a national one, and if, in addition to this, the recommendations of the present Royal Commission on sewage purification concerning the creation of a special department for the supervision of rivers is carried into effect, a great improvement is sure to result. Unsystematic treatment of many questions in the past has, we are frequently told by political speakers, led to many disadvantages. It is to be hoped, therefore, that learning from the experiences of the last century, we may avoid its errors in the present.

The task which the author set himself is nearly done, but he cannot close his remarks without expressing his very best thanks to all those gentlemen near and far who have kindly supplied him with information or have even carried out experiments on his suggestions.

Whether at the end of the present century the sewage question will still disturb the minds of many, or whether it will have been solved to the satisfaction of all, is to-day a mere matter of speculation. The chances are that there will still be many opinions; but be that as it may, what is of importance to us, living in the present day, is that we should carefully examine everything, and retain the best.

DISCUSSION.

The PRESIDENT said that the meeting had had from Mr. Roechling a very unique paper, inasmuch as it gave a summary of the sewage question practically from its commencement. The paper would be a great addition to their 'Proceedings.' Further, it would give them individually a valuable addition to their text-books. He was sure that the paper would be one of very great importance and utility, if only as a book of reference, for it concisely summarised the whole thing. The author referred in his paper to his work at Leicester. He (the President) had the pleasure of being connected with Mr. Roechling on the

Leicester sewage farm, and he was under the impression that the soil of that farm had been materially helped by the discharge upon it of the ashes from refuse bins, and he ventured to think the reason that the soil had changed was partly due to such admixture of ashes.

Mr. Roechling had remarked upon the management of sewage farming. That was in his (the President's) opinion a matter that ought to be more seriously considered by those who had the organisation of municipal affairs. Engineers designed farms, and had them working well in the initial stage, and a few months after the system was set up the whole thing might be handed over into the hands of farm labourers, or persons very little better qualified for their duties, and in consequence of the farms having been left in unskilled hands, sewage farming had, in many cases, been said to be a failure. He thought that the meeting would agree that such failures were due more to mismanagement than to the original conceptions of the engineer. He concluded by proposing a hearty vote of thanks to Mr. Roechling for his paper.

The vote of thanks was carried by acclamation.

Dr. RIDEAL said that it was an easy task to look back upon the failures and successes of past centuries and to criticise them in the light of our present knowledge. Mr. Roechling had omitted the more difficult one of predicting the future development of sewage treatment in this country. Many arguments had been introduced in favour of what he might call the sewage farm of the last century, but he hardly thought that they would hinder present workers from perfecting the newer bacterial methods. The author had dealt with some experiments made by Dr. Dunbar, some years ago, with contact beds. That was a method of treating sewage bacterially which he (Dr. Rideal) had repeatedly said was totally wrong in principle. It was a mixing up of several different processes, and consisted in an attempt to bring about the preliminary breaking down, and the final oxidation in the same tank alternately. There was now no doubt that the changes which took place in a contact bed depended on a variety of organisms, some anærobic and some ærobic, and it was contrary to all scientific and business principles to expect totally different processes to succeed under the same conditions. It was indeed quite possible that Dr. Dunbar was correct in saying that in a contact bed the liberation of carbonic acid took place in an indirect way, but even if they got an evolution of carbonic acid, not directly from the action of the organisms, but indirectly by the production of, say, lactic acid, the latter was also the product of other organisms. Therefore he thought that it was a quibble to say that the carbonic acid was not the result of bacterial action. It was the result of bacterial action, as they would see if they were acquainted with the processes by which the lactic acid was produced. It was well known in water purification that the humic acids which had plumbo-solvent properties, were the result of bacterial action, so that that chemical property of certain waters was strictly a bacterial one.

Again, every one knew that through the action of micro-organisms in a bacterial bed there was a certain deficiency of oxygen produced. The oxygen was absorbed and disappeared, and the disappearance of the oxygen was due to bacterial action. He should, therefore, substitute the word "certain" for the word "possible."

The author accepts the classification of the Royal Commission of one natural method of sewage purification—the others being artificial. That was very convenient, but one must recollect that an artificial method was only successful in so far as it was based on natural processes. It was impossible to draw a hard and fast line. A sewage farm was, in a certain sense, an artificial method of dealing with sewage. It was man making use of natural agencies to bring about a given result; and whether they dealt with sewage by means of a piece of land, or a bed of coke, or a bed of brickbats, those materials were utilised by the natural organisms which determined the chemical purification desired by man. He objected very strongly to the general division which the author had made.

Then he would take objection to the statement that the sewage farms on clay land gave such fair results as warranted such a method of disposal being imitated in the future. He would refer to Mr. Cooper, who was present and who knew more about it—the Wimbledon clay farm—than he (Dr. Rideal) did. The President had referred to Leicester. He (Dr. Rideal) contended that neither Leicester nor Wimbledon could be cited as clay farms giving fair results. They were examples of clay soil which by artificial treatment had been made to give fair results. They were not examples of clay soil by itself giving good results. The author stated that the Royal Commissioners were of opinion that it was practicable to produce by artificial processes alone, effluents which might be discharged into a stream and that the report did not specifically state what those artificial processes were. He (the speaker) read the report when it came out, and he had a very clear recollection in his mind that the commissioners had definitely said that there were known to them ten different artificial methods, and that all ten processes were, with proper safeguards, suitable as alternatives to land treatment. Those ten processes were divided up into two batches of five each. The second batch of five consisted of methods in which the final treatment was continuous filtration.

The author had not said a word about continuous filtration. His criticism of bacterial processes had been entirely confined to the first five alternatives of the Commission, which involved the use of the old-fashioned contact bed, and which he ventured to think was likely to be heard of very little in the present century, for the reasons he had already indicated.

The author had taken micro-organic life as an indication of the presence of polluting substances. If they had no polluting substances, they would still have microbic organic life in the soil, so that the converse was more correct, the life following after the pollution and getting rid of it.

In dealing with the retention of impurities by the soil, hydrolysis, as well as combustion took place. The soil would take up a certain amount of sewage, and then, after that, the changes that took place were microbic changes or bacterial changes. A piece of ignited coke had the mechanical property of absorbing ammonia and sulphuretted hydrogen, but after that had been done, the further change that took place must be a chemical or bacterial one. Dry soil very quickly lost its retentive power, and chemical purification in that way was of a very limited character.

With regard to the action of lime, they knew that lime was a good solvent for organic matter, and that would be a phrase acceptable to the chemist, as well as to the engineer. It was hardly correct to say that that base attacked and split up organic matter. Further on in the paper they came to something which was more to the point. They talked of bacterial change, and bacterial purification of sewage, but one ought to realise that the number of bacteria was not necessarily the measure of the quantity of water purified. One ought to bear in mind, in dealing with the question of the number of organisms found in the effluent, that that had no relation whatever to the number of pathogenic organisms, or even of the original sewage organisms. It was perfectly true that in contact beds where the beds were filled up and emptied, they got a mixture of the organisms of the crude sewage and those which lived in partially purified sewage, therefore the bacteria which came out of the contact bed were always mixed in character. That was not true in a filter or land, as zones of different bacterial species were produced, so that a sorting of the organisms took place, with the result that the effluent might contain theoretically none of the original bacteria of the sewage nor of their progeny. In continuous pickling filters, the anærobes were gradually replaced by ærobes, and the number of coli organisms present was reduced. Therefore, if one was aiming at the reduction of the pathogenic organisms and the removal of them, it was essential that there should be a real oxidation at the last stage, such as they could not get in a contact bed, and such as obtained in a perfect sewage farm and in a good oxidising continuous filter. The statement respecting the influence of frosts was surely an argument in favour of contact beds. In frosty weather the warm sewage coming on to the continuous filter, would not freeze as quickly as when it was spread out on the surface of the frozen clay sewage farm.

With regard to the presence of pathogenic organisms in effluents, he did not see why it should be necessary for the sewage farm or bacterial filter to produce an effluent capable of being drunk further down the stream. He thought it was the duty of the waterworks engineer to purify that supply if he elected to take water from a river, and that one ought to be content with an effluent which did not kill fish nor prevent the river from being used for boating or bathing. If it was absolutely necessary to kill off pathogenic organisms, it was very easy to effect that by a very small quantity of chlorine, ozone or other oxidising agent. Ozone was being tried by one of the metropolitan water companies for reducing the number of organisms in London water, and he had obtained excellent results at Maidenhead with chlorine on a bacterial effluent.

One point which Mr. Roechling had alluded to, was the discharge of the nitrates into the river and the consequent production of algæ and the blocking up of the river. It was true that the nitrates favoured vegetable growth, and if the effluent was put on to the land the crops thereon would be increased. If land was not available and the blocking up of the river was feared, it was quite possible by bacterial action so to adjust the quantity of nitrates to the quantity of crude sewage that the oxygen of the nitrates would react on the organic nitrogen of the crude sewage, and thus remove from the effluent most of the combined nitrogen.

The evolution of gaseous nitrogen in that way was shown in the analysis of Dublin harbour waters in the recent papers read before the Institution of Civil Engineers, by Mr. Kaye Parry and Dr. Adeney. Every one who had analysed the effluent in a sewage farm, and had compared the nitrogen of the effluent with the nitrogen that existed in the sewage, would find that there was a disappearance of an immense quantity of nitrogen. That evolution of nitrogen was due to bacterial action, and it should require very little technical skill to adjust the bacterial life, to ensure that the whole of the nitrogen should go off as gas and leave no combined nitrogen in the effluent, if such a course was to be desired. He did not, however, anticipate, that the fertilising property of bacterial effluents would be so intense as to cause the blocking up of our rivers with algæ as feared by Mr. Roechling. Algæ ponds similar to the ulva latissima ponds proposed at Belfast, would remedy the difficulty.

Colonel ALFRED S. JONES, V.C.: said, that when he attended a meeting of the Society of Engineers in 1896, a paper was read by Mr. Thudichum. Then sewage farms were going to be abolished and some millions presented to the country in honour of the Jubilee of 1897. He welcomed the present paper very much. The author had fulfilled his intention of reviewing the principles which underlay this apparently inexhaustible question. He could confirm the author's conclusions from his own experience in almost every particular.

He was glad that the author had clearly stated the position of M. Pasteur with regard to sewage as applied to the land. In the first instance, Pasteur was opposed to the application, but he was converted by further information. In the same way the Royal Commissioners were afraid of the coli bacteria coming out of the effluent, though they admitted that there were less in the sewage farm than in the contact beds, and the testimony of their final report after further experiment may, like that of M. Pasteur, be all the stronger from the fact of their preliminary anxiety.

The author had noticed two failures in the bacteria arrangements or installations, the one in Bavaria and the other at Aldershot. He (Colonel Jones) had looked the matter up with regard to the failure at Aldershot, and he did not think it was fair to attribute it to any one of the processes which had been recommended, because it was a kind of confused reading of Mr. Dibdin, Mr. Scott-Moncrieff, and others. The arrangement was a perfect jumble, and he did not think it ought to be taken as a failure of any one of the systems. Complete failure was admitted, and the War Office had recently invited him to take the management of that installation and of all others in the Aldershot district, and to manage them on the system of simple irrigation.

With regard to Dr. Houston's experiments for the London County Council, mentioned in the paper, if there was any County Councillor present he would like to bring to his mind the proposals that were made to the Metropolitan Board of Works prior to 1885, or in the years 1881 and 1885. They were taken up by Lord Bramwell's Royal Commission on the Metropolitan sewage discharge. That commission recommended precipitation as a temporary measure; but they distinctly demanded as a permanent remedy, that neither the solids nor the liquids should be discharged at any place higher up than Hole Haven. It would be worth while for the County Council to look up that matter before they finally decided the question.

Dr. Rideal had referred to the growth of algæ in consequence of the discharge of nitrates into the river from sewage farms and bacterial beds, and more especially from the latter; but he had left altogether out of sight the nitrogen consumed by the plants in the sewage farms. The streams below the sewage works on the river with which he was connected were constantly cleaned out every year at the expense of the ratepayers, and he observed an immense growth of weeds which he believed were very much due to the nitrogen which was allowed to escape after artificial processes and in storm-water overflows.

As to the necessity of good management for sewage farms to which reference had been made, he made a special point of that in papers which he read before the Society of Municipal and County Engineers, and the Sanitary Institute, some six or seven years ago. The subject was brought up again two years ago by Mr. R. Royle, in a paper read by him, in which he endorsed a recommendation which he (Colonel Jones) ventured to make to county councils generally. The recommendation was that they should apply some of the technical education money, which many of them hardly knew what to do with, to the endowment of a sewage farm or some really good sewage works in their neighbourhood with scholarships or premiums to induce agricultural labourers to work on sewage farms and obtain certificates, not only as managers but as labourers, or what were called watermen, or workmen of any kind to be employed in any part of sewage works, whether in connection with bacteria beds or chemical precipitation or otherwise. There was a great need for the right men. It was all very well to complain of local bodies; but those bodies could not always find the right men to carry out the work.

Major-General Carey, R.E., said that the paper was a very interesting and careful *résumé* of the whole question of sewage treatment. He agreed entirely with the main points. The subject of good management, a point which had been emphasised by Colonel Jones and others, was a very important matter whatever system was adopted. There was no doubt that a very large number of failures had been brought about by bad or indifferent management. Sanitary authorities would have to be prepared in the future to put their works under more skilled management than they had done hitherto.

Mr. C. H. Cooper said that the clay of the Wimbledon Sewage Farm did not afford any evidence that sewage irrigation caused such clay to disintegrate. Sludge cakes, which contained a large proportion of lime, did, however, disintegrate clay, but he doubted very much if such disintegration was of a lasting nature. When the late Mr. Santo-Crimp went to Wimbledon there was practically no soil on the farm, the clay coming right to the surface. The only fields on which sewage could be treated were those which had not been drained. Those fields took the high level sewage which was rather weak, and was then about 70 gallons per head.

He did not agree with Dr. Rideal that sewage could not be treated on clay land, for at Wimbledon, after the leakage to the subsoil drains was stopped, a very good effluent was obtained. But the quantity of sewage that could be treated on clay ground was small, and it was to increase the capacity of the land for treating sewage that house refuse and road detritus had been dug in so as to form the soil which now covered the farm.

A vital point as regarded the treatment of sewage on land, whether it was impervious, as in the case of clay, or porous, as in the case of gravel, was that of maintaining the surface with uniform falls, so that there was no liability for water to lodge or stagnate. Wherever the sewage admitted on to land stagnated, the crop was damaged and a nuisance created.

The author was perfectly right as regarded the necessity for thoroughly capable managers to take charge of sewage farms. It too often happened that sewage works and farms were in the hands of persons who never saw sewage until they took charge of the intricate problem of sewage treatment, and it was not to be wondered at that the problem, when entrusted to such management, should have failed.

The simple expedient of keeping carriers and ditches which convey sewage clear was neglected in some of the principal sewage farms in this country. In one of the largest farms near London, sewage had been allowed to stagnate in the channels and carriers conveying it on to the farm, and, as a result, legal proceedings for nuisance were threatened. The effect of frost, even in America, did not prevent sewage being treated in the Massachusetts filters, and in this country sewage could be treated on land during the severest frosts.

There appeared to be little doubt that the greater part of the purification of sewage took place near the surface. According to the results obtained by the Massachusetts State Board purification practically ceased at certain depths.

The author alluded to certain failures of open septic tanks, but it was a great pity that those failures were so frequently alluded to, as no provision had been made in such tanks to preserve the scum which appeared essential for the liquefying organisms which effect the septic action.

Mr. John D. Watson said that the paper was a very clear *résumé* of what had been done in the way of sewage purification during the past century. At Birmingham great difficulty had been caused by the sewage sludge. The population of the district represented by the Birmingham, Tame and Rea District Drainage Board (which includes the City of Birmingham) was three quarters of a million, and the quantity of sludge which had to be dealt with every day was very large. Until two years ago the Drainage Board adopted lime treatment in the proportion of 9 grains per gallon. The nuisance occasioned by the disposal of the sludge became so great that he stopped the use of lime. He was strengthened in taking this course by the results obtained by Dr. Rideal and other bacteriologists, and he now agreed with them that in using lime they were precipitating the very organisms which materially assisted in the purification of the sewage. Objection had been taken to septic tanks, especially where they were open, but at Birmingham they had acres of open septic tanks and they were not a nuisance; even the most fastidious could not complain of smell being emitted from them. The use of septic tanks had had the very great advantage of reducing the quantity of sludge by about one half. As the amount of suspended matter in the septic tank effluent was greater than the amount of suspended matter in lime-treated sewage after it had undergone the sedimentation process, he feared that the septic tank effluent might lead to the chokage of the great sewer. He had watched that carefully, and was pleased to say that there was no more suspended matter in that sewer to-day than there was two years ago when the liquefying process was started. He believed that was due to the 8-foot conduit, which was 5 miles long, acting as a covered septic tank. He also found that the septic effluent was more easily treated on the land than lime-treated sewage, and that the process of putrefaction and fermentation which went on in the open septic tank, and subsequently in the sewer, which was ostensibly a closed septic tank, really broke down the organic substances in the sewage, and that the land was capable of dealing with more water than it did before the change. The scum which was formed on the land by the humus from the septic sewage was less objectionable than was feared. It did not acquire the glutinous consistence that the lime-treated scum had; it cracked readily and allowed the air to pass much more freely into the ground than the lime-treated scum did. Thus they had been able to assist the land itself as well as to reduce the sludge nuisance at the tanks. There was a very important point with regard to crops. The fertilising properties of the septic tank effluent seemed to increase the growth of vegetables, and by that term he included all kinds of crops. They had all kinds of crops and all kinds of soils on this sewage farm.

He inclined to agree with what Dr. Rideal had said with regard to the classification of the processes into natural and artificial. Land treatment was essentially bacterial treatment, and if, as he pointed out, they had a good result in the treatment of sewage on land, he did not see why they should not have an equally good result on a bed which had been specially prepared for the treatment of sewage. In point of fact the result ought to be better in the latter case. In the case of Birmingham the land of the sewage farm consisted of very varied strata, and he thought that treatment on an artificially prepared bed was in some respects preferable to treatment on land which was of such a varied character that it was impossible to judge the amount of purification with which a specific acre was capable of dealing.

He agreed with those speakers who had expressed themselves strongly on the question of management. Beneficial results could not be got unless the management was good. Sewage farms had been blamed for being inefficient and unable to perform the work expected of them, and a very unjust reaction had set in against them. Authorities who had refused to those who had the management of them sufficient money to work the land properly, were largely responsible for that. All honour was due to bacteriologists, chemists and others who had really done so much to advance the present question, and anything which appeared to belittle those discoveries and methods was to be deprecated, but, on the other hand, there could be no doubt of the fact that, given suitable land and plenty of it, there was no method of sewage treatment better than a good well-managed sewage farm.

Mr. SYDNEY F. WALKER said that as an electrical engineer he would ask whether electricity had been tried in any form to assist the sewage problem. It had struck him that, if sewage engineers had not made use of electricity, they had neglected one of the most useful and powerful agents which lay ready to their hands. It seemed to him, as far as he understood the question, that electricity had properties which would be of great value. An electric current passed through sewage would decompose a large portion of it, and incidentally it would generate considerable quantities of oxygen and of hydrogen. He took it that oxygen gas was one of the things that they were in want of. He understood that one of the principal factors in the purification of sewage was the passage of the effluent through a bed which was more or less porous. The electric current had a remarkable property of being able to assist that process. That was to say, if an electric current was passed through the beds through which they wished the sewage to go, it would increase the rate of passage and carry the effluent downwards. He could quite understand that electricity might not have been tried in the past, there having been no sufficient source of electricity, but that objection could hardly rule now. There were plenty of sources of electricity, and they could have as much as they wanted.

Mr. **Douglas Archibald** said that the paper was conceived on very broad lines; but it struck him that Mr. Roechling had entirely left out all reference to chemical treatment; and he had also made it appear as if the Royal Commission report had left it out as well.

Dr. Rideal had forestalled him (the speaker) with regard to one criticism. The author said "land treatment has been re-established by the Commission now sitting, in its position as the first and only natural method of sewage treatment, and that beside it certain artificial (biological) methods have been recognised." It looked from that passage as though there were no artificial processes except the biological. The reports specifically mentioned chemical treatment and subsidence tanks and filters as one of the processes referred to, and there was also a footnote to say that subsidence tanks meant tanks in which no septic action took place; so that another artificial method besides the septic and biological was clearly indicated. Any one reading Mr. Roechling's paper would imagine that the Royal Commission had simply excluded chemical action altogether. He would not here attempt to dilate upon the relation between chemical and bacterial action, but it seemed to him from his experience that it was mainly the question of management that determined the present position of chemical treatment. If chemical treatment had been properly carried out both in regard to quantity and quality it would, he thought, have been in a much better position now. While upon the question of management, he would suggest that there might be a department of state to examine sewage works. If they were to have all the sewage disposal works placed under Government inspectors, and a kind of episcopacy established to see whether they were properly conducted, they would get better results. That idea might sound very Utopian. He merely suggested it.

As regarded the question of the treatment of sewage, chemically first, and bacterially afterwards, it always seemed to him that if all the solids were deposited in the tank to start with, and they got an effluent without any suspended matter in it, and that effluent were then passed through a bacterial filter, whether it was what Dr. Rideal termed the old-fashioned contact bed or the continuous filter, it would be better than leaving out chemicals and trusting to septic decomposition only. Surely it would be better to have all the solids dealt with at first in the tank, for then the bacteria would not have so much to do. The bacteria would not eat the whole dinner, but they might come in like the children for the dessert. It seemed to him that they could thus effect the entire processes better upon a limited area than they could with a septic tank whether open or closed.

The present position of chemical treatment with regard to the Local Government Board might be inferred from their rule, which was that, for chemical treatment in tanks, followed by filtration, they required only one acre of land for two thousand inhabitants; whereas, for septic tank treatment with filtration they required one acre for every one thousand inhabitants. According to that, chemical treatment was put on the basis of being doubly as good as septic treatment.

He had found that chemical treatment, properly carried out, and so that all the solids were deposited, enabled the effluent to be filtered on a contact-bed of one-sixth the area that must be used for a septic tank effluent. A septic tank effluent required three acres for every million gallons per day, whereas, if there were proper chemical treatment, half an acre of filter only was really necessary to deal with one million gallons, the latter area being one-sixth of the former for the same flow.

Another point which had been alluded to was that in the case of a septic tank system there must be continual renewal of the filters. Mr. Roechling mentioned that in one case the cost of such renewal was 250*l*. per annum. He should like to know what the area of the filter in that case was, so that he might see the proportion between the cost and the area. In any case that point must be seriously considered in the future. Everybody knew that however suitable a septic tank effluent might be for land, it contained at least 10 grains of suspended solids per gallon, and if those solids went on the filter they evidently were solids which were not capable of being liquefied in the tanks, and were likewise not capable of being liquefied in the filter. Consequently the filters following septic tanks get choked up; and in most cases the rate of choking was such that for a septic tank treatment it took only three years for the filter to choke up entirely, and where there was no tank it took sixteen months. The question of filter renewal would have to be considered when they took up any of such systems practically. The question of septic sludge removal would also have to be considered. The removal of the sludge from the septic tanks was put off from day to day until an enormous mass had to be removed. It was stated in the paper read by Mr. Hetherington at the last meeting of the Society, that, in one septic tank, there was so much sludge that a man was able to walk across it. The other day he saw a septic tank, the top of which he was sure a child would be able to cross without sinking in. Points such as that seemed to him to militate against the application of the septic tank system. There were ample safeguards, in proper chemical treatment, against such evils, and he could not see why chemical treatment should not be generally employed as the preliminary stage, and the effluent from the chemical tank treated bacterially afterwards. By means of proper chemicals a valuable and saleable sludge could always be produced, instead of a sludge which cost a shilling a load for removal.

Mr. Scott-Moncrieff, said that the paper dealt with the subject as a whole rather than with the more advanced forms of bacterial treatment. He had seen the tanks at Birmingham to which Mr. Watson had referred, and they were certainly an exceedingly interesting illustration of the change that took place under anærobic conditions. The crust on the surface of the beds was very characteristic, and he could confirm the statement that there were no offensive smells. When he saw the tanks, lime was being used as a precipitant. He would ask Mr. Watson whether he included the detritus in his estimate of the residual sludge. If the inorganic detritus was common to both systems, i.e. the bacterial anærobic system and the treatment by lime, it fairly ought to be deducted in estimating the efficiency of the bacterial treatment, which of course had reference only to the organic matter in suspension.

The change which occurred in the bacterial purification of sewage was dependent upon well-known conditions which had come into evidence and been more highly developed during the last few years than at any previous period in the history of the sewage problem. It was clear that, in the anærobic change, results such as those claimed by Mr. Watson were available for all and sundry who did as Mr. Watson had done. Similar substances similarly treated would no doubt be acted upon in the same way, whether in England, in France, or in Germany. Microbes had no nationality. It was dangerous to argue from one case to another, unless they were sure that the underlying conditions were in all respects identical. The statements which hailed from Germany were obviously founded upon different data from those which hailed from Birmingham.

The anærobic changes took place in an anærobic tank, whether it was open or closed, or in a cultivation tank such as he used in 1892. There were advocates for having surfaces in the septic tank available in the form of large stones for the retention of the organisms, and he thought that there was evidence to show that those had advantages. He never maintained that it was necessary, for it did not appear to be an essential element at Exeter. When, however, one came to the oxidising changes which supervened, the difference between contact beds and percolating beds was a difference in kind and not merely one of degree. The first change, due to anærobic fermentation, produced gases that were inflammable. On the other hand, gases which occurred in the oxidising process were gases which put out a flame. In a badly ventilated filter-house a candle was put out two feet above the level of the floor. That was only one object lesson to show how essentially different the two processes really were, and to mix them up or to attempt to make them act alternately in the same bed was a great mistake. To generalise and say that one process—a sewage farm—was natural, and the other—a bacterial bed—was artificial, because the surfaces in one case were in a field, and in the other in a filter bed, was to make a distinction without a difference.

It was quite certain that, in order to produce an effluent of a high standard of purification, in terms of the ratio of oxidised to unoxidised nitrogen, a certain standard of air, as well as a certain standard of surface was necessary in all cases. Failures were due to the lack of either one or the other, or both of those essential factors. If sufficient surface and sufficient air were provided, and sufficient time given for the organisms to establish themselves, it was absolutely certain, whether in Germany, in France, or in England, that there would be a given standard of purification in terms of the ratio of oxidised to unoxidised nitrogen. That being so, all that was now wanted was an accurate knowledge as to the amount of surface and the amount of oxygen necessary to produce the required change in any given sewage. It was absolutely certain that the organisms were available; it was certain that nature would complete the work; and it was certain that, when nature had completed the work, the question of purification and of the highest manurial value would be realised in one and the same process. That was to say, if they got the highest purification in the terms of the highest ratio of oxidised to unoxidised nitrogen, they would get, in the best sense of the term, the most perfectly purified sewage.

Mr. ROECHLING, in replying on the discussion, remarked that the President had referred to his (the speaker's work) on the Leicester Sewage Farm, which had been of a pioneering nature, and had stated that in his opinion the change in the character of the clay soil had to some extent been brought about by the spreading of ashes over the land. That was undoubtedly correct, but later on it had been found, that the action of sewage alone was very beneficial in that respect, and in consequence of that, the spreading of the ashes had now for some years been discontinued.

He agreed with everything that had been said by the President concerning the management of sewage farms, and it was sincerely to be hoped such delicate pieces of machinery would in future not be handed over to the tender mercies of agricultural labourers or others who had not the faintest idea of how to use them.

Dr. Rideal had criticised various parts of his paper, and had commenced with finding fault with him for undertaking so easy a task as that of reviewing the past, and for not acting as a prophet in fortelling the future. He (the author) had no wish to indulge in visionary forecasts; he was an engineer, and as such accustomed to deal with hard and dry facts, and would gladly leave speculation as to the future to those who did not mind jumping at conclusions. An engineer could only get over a chasm in reasoning by constructing a bridge to carry his thoughts across, but others might be able to accomplish that by the creative flight of their imagination, which might and sometimes did land them in the region of dreams.

Dr. Rideal seemed to dislike sewage farms because they were institutions of the last century, and because something more modern must be put in their place. He (the author) preferred, however, not to express any such general likes and dislikes. He was prepared, if it could be proved to him conclusively that nature was not sure and true enough in its methods, to assist it with methods and means produced by the inventive brain of man. But if such proof were not forthcoming he would, in preference to groping in the dark, adhere to nature's own methods, knowing from experience that when allowed full scope and fair treatment it was most sure in all its ways. That would not prevent him, however, from giving in the future, as he had done in the past, the question of sewage treatment his most careful consideration.

Dr. Rideal had very strongly objected to dividing up, as he had done, all sewage purification methods into two main classes, viz. natural and artificial methods, but it appeared to him, had he not placed the so-called bacterial methods in the artificial class, that strong objection would not have been raised. However, the present Royal Commission had used the same divisions, and he thought Dr. Rideal was labouring under a misconception.

For main divisions of sewage purification methods, two things appeared to be of primary consideration, viz. the agencies at work and the way those agencies were employed. Was it possible to use the agencies at work as a distinguishing feature? He thought not, for all agencies were natural, and there could not be such a thing, at any rate in the present state of their knowledge, as an artificial agency. Whether they employed a purely chemical process, a bacterial process, a sewage farm or a combination of them, the agencies at work were all natural, i.e. made by nature and not artificial, i.e. made by man. They must, therefore, fall back upon the second point, i.e. the way in which the agencies were employed, and here it was no longer open to argument, that the contact bed system and all other so-called bacterial methods were artificial, and land treatment natural. For even the merest outsider could not deny that earth, concrete or brick tanks with coke and brick-bats in them were artificial products, i.e. made by man, and that land was the natural product, and that the natural home of bacteria was the soil, and not coke, brick-bats, etc. Hence all the objections raised to that method of dividing up the sewage purification terms fell to the ground and must disappear.

Dr. Rideal had objected to sewage farms on clay soils as not having proved successful, and he had mentioned Leicester as a case in point, but Dr. Rideal had not told them that the Leicester Corporation had just acquired the freehold of the farm for about 160,000*l.* That fact, he thought, spoke for itself.

Dr. Rideal had further stated that "dry soil very quickly lost its retentive power." He (the author) had to admit he did not fully understand the meaning of that sentence. A certain kind of soil had a certain retentive power, and did Dr. Rideal suggest that dry soil could take up less moisture than wet? if so, that was against well established facts. Or did Dr. Rideal mean to say that dry soil quickly lost moisture by evaporation?

As to the employment of lime on sewage farms, Dr. Rideal's remarks confirmed the favourable view he (the author) had formed of it.

Dr. Rideal strongly attacked the contact or oxidation bed system as being totally wrong in principle; it was further, so he said, old fashioned, and was likely to be relegated to obscurity before long. It seemed strange, if that was so, that the present Royal Commission should have considered it worth their while to recommend it. But, as they had done so, the inference must be, that they did not agree with Dr. Rideal.

Then he (the author) had been found fault with for not introducing the subject of continuous filtration as distinguished from intermittent filtration or contact beds. There was a very simple reason for that, viz. that he did not think sufficient evidence had yet been produced to form a definite opinion about it, and he was very anxious not to do or say anything that might in any way create a prejudice against or otherwise interfere with those experiments, which he should like, on the contrary, to see considerably more extended. It was only in that way that proper conclusions could be formed.

Concerning the action of frost upon contact beds or continuous filters, he thought they had not yet sufficient data to form definite views, but they knew that sewage farms when well managed did not create difficulties in very cold weather. If experience with continuous water filters was any guide, he could say that he had seen open filters, both in this country and aboard, frozen over, and that the removal of the ice created very great difficulties.

The bacterial condition of the effluent from artificial self-purification works was anything but satisfactory ; in that respect the effluent was practically raw sewage, and there could be no doubt that the legislature would not tolerate the wholesale admission of disease germs into their streams. If that were allowed, then the necessary consequence would be to give up all surface water for drinking purposes and to establish new water supply works from underground sources.

As to the discharge of nitrates with the effluents of artificial self purification works into our rivers, he was glad to find that Dr. Rideal admitted that might become an element of danger in the way of too luxuriant river vegetation. Whether, however, the remedy proposed by Dr. Rideal would prove a real one remained to be seen ; he (the author) doubted it very much, and so far at any rate the results obtained from artificial self-purification works had been in the direction indicated by him.

Whilst Dr. Rideal strongly condemned the oxidation or contact bed system, he had advocated continuous filters, followed first by special treatment for the removal of nitrates, and afterwards by sterilisation for the destruction of pathogenic germs. That was a series of complicated processes in substitution of land treatment ; and did Dr. Rideal really think that three or four processes were simpler and cheaper than one ? He (the author) thought not.

He was very glad that Colonel Jones had given them the benefit of his experience as a sewage farm manager of many years' standing. Colonel Jones had done more than anyone else living to establish correct views on sewage farming, and he had lately changed the Government sewage marshes at Aldershot into a veritable Garden of Eden, watered by the water from the Aldershot camp, growing healthy crops and causing not the slightest nuisance. That was an achievement of which anyone might be proud! He (the author) spoke from what he had actually seen and observed, as he had been over the farm in the time of the "deluge," and afterwards when order and system had been evolved out of chaos. The War Office owed Colonel Jones a deep debt of gratitude, for he had pulled them out of a deep hole and saved them from 50,000*l.* to 100,000*l.* by keeping the camp farm in its present position.

The present was not the place to make suggestions as to the education of managers of sewage works, but there could be no doubt that an improvement in that respect was an absolute necessity, and he hoped the present Royal Commission would take the matter up.

He (the author) was very glad to gather from Mr. Cooper's remarks, that he did not agree with Dr. Rideal as to the unsuitability of clay soils for the treatment of sewage. He (the author) had referred to Wimbledon as a successful instance of sewage treatment on clay land, and he was pleased to observe that, according to Mr. Cooper, the land continued to do its work well. It was quite true, as Mr. Cooper had remarked, that the quantity of sewage that could be treated on clay soil was smaller than that which could be treated on other more open soils, and for that and other reasons they would not select clay in preference to a more porous material for a sewage farm. He was also glad to note that Mr. Cooper stated that in this country sewage could be treated on land during the severest frosts.

Mr. Watson had given them his valuable experience on the Birmingham sewage farm, which seemed to bear out the remarks he (the author) had made, when speaking of a combination of natural and artificial methods of self-purification of sewage, and the experiments thus commenced, deserved to be watched with the greatest interest. Mr. Watson, whilst giving well-deserved credit to bacteriologists and chemists, had summed up his remarks in favour of land treatment, and that was all the more important considering the opportunities he had of forming correct conclusions.

Mr. Walker had asked whether electricity had been employed in connection with sewage purification, to which question he (the author) would reply, that this had been done years ago, and that after extended experiments electricity had been given up. He (the author) did not think, however, that the electric current had been used in connection with contact or oxidation beds, and the point to be considered was, whether the results to be obtained would justify the expenditure.

Mr. Archibald had directed their attention to chemical treatment, and had suggested that he (the author) had not mentioned that amongst the recommendations in the Interim Report of the Royal Commission was one in favour of chemical treatment followed by a bacterial process. That was quite correct, and what he (the author) intended to say, and thought he had said, was that chemical treatment *per se*, and not assisted either by the natural or one of the artificial processes of self-purification, was not recommended by the Commissioners. Mr. Archibald had further dwelt upon the advantage of a previous chemical treatment over a previous septic tank treatment, and some of his suggestions were well worth careful consideration, but of course it remained to be seen whether his anticipations would be realised.

Mr. Scott-Moncrieff had drawn attention to the different nature of the processes taking place in septic tanks and oxidation beds, and had expressed himself in very confident terms that all that was now wanted was an accurate knowledge as to the amount of surface and the amount of oxygen necessary to produce good results. He (the author) wished he could share Mr. Scott-Moncrieff's optimism, but as he had pointed out in his paper, it appeared to him, that up to now, we knew very little of the intricate processes taking place in the self-purification of sewage, and what we knew was frequently in a very confused condition, owing to the very confusing results obtained by various experimenters.

Obituary.

NORMAN HARKER, whose death occurred on May 24, 1901, was born at Hornsey on November 2, 1873. After a general education he entered, in 1892, upon a two years' course at the Crystal Palace School of Practical Engineering, which he passed successfully. He was subsequently engaged in business in the office of his father. Mr. Harker was elected an Associate of the Society in December 1892.

HUGH McINTOSH, whose death took place on May 30, 1901, was born in London on January 21, 1826. He was educated in Exeter, and upon leaving school was articled to Mr. Charles Dean, C.E. He was subsequently engaged, under the Metropolitan Board of Works, as assistant to Mr. Grant, the engineer to the Board. In 1856 Mr. McIntosh was appointed Chief Surveyor of the Vestry of Lambeth, which appointment he held until his retirement in 1894. The deceased gentleman was elected a Member of the Society in 1868.

ALFRED JOHN BEWICK WARD, who died on November 7, 1901, aged 46, was a son of the late Mr. Robert Ward, of Newcastle-on-Tyne. He was educated at the Royal Grammar School in that city, and commenced his professional career with a firm of civil engineers. He was afterwards articled to the late Mr. John Johnston, architect, of Newcastle, with whom he remained for some years. In 1881 he came to London, where he established and managed the business of Messrs. W. B. Wilkinson and Co. About ten years ago he relinquished that appointment, and founded the firm of B. Ward and Co., concrete specialists. Mr. Ward was elected a Member of the Society in 1892.

CHARLES FREDERICK SMITH, whose death occurred on December 19, 1901, was born on February 19, 1864. After a liberal education he became engaged with Mr. T. Sopwith, C.E., of Westminster, in whose London office he remained for five years, after which he proceeded to Linares, Spain, where he took the management of various mining undertakings for Mr. Sopwith. He subsequently had to leave Spain owing to ill-health. Mr. Smith was elected an Associate of the Society in 1887.

ANNUAL REPORT OF THE COUNCIL, 1901.

In presenting their Annual Report for the past year the Council have the pleasure to record the election, in the beginning of the past year, of Sir Andrew Noble, K.C.B., F.R.S., and Professor William Cawthorne Unwin, F.R.S., as Honorary Members, thus filling the vacancies created by the decease of Lord Armstrong and Dr. William Pole in the previous year. They are also pleased to be able to report an increase in the numerical strength of the Society, notwithstanding serious losses from deaths, resignations and other causes.

The Membership Roll.

The following statement shows the muster roll of the Society at the close of the year 1901, and the two preceding years.

Class.	Dec. 31, 1899.	Dec. 31, 1900.	Dec. 31, 1901.
Honorary Members	20	18	20
Ordinary Members	246	246	252
Ordinary Associates	132	128	122
Foreign Members	69	64	69
Foreign Associates	33	30	30
Total Membership	500	486	493

Associates' Meetings.

In the early part of the year the Council had under consideration the question of special meetings for Associates, at which papers prepared by Associates under 25 years of age, on engineering subjects, should be read and discussed. It was proposed that those meetings should be held at the offices of the Society in the evening, and be presided over by a Member of Council, and that attendance should be limited to Associates, and to such visitors, not being members, as they might introduce. In connection with the proposal, Mr. G. Maxwell Lawford, a Past President of the Society, offered an annual Premium of the value of three guineas, for the best paper prepared by Associates under the age of 25 years, and read during the year at an Associates' meeting. It was thought that such meetings, being of a less formal character than the ordinary meetings and being confined to the young engineers who form so important a section of the Society, would offer opportunities for the expression of opinions and the interchange of experiences or ideas which could not but be of great value and assistance to those who felt a reluctance to read papers or take part in the discussions in the presence of the older and more experienced members.

Before attempting, however, to carry out the proposal, the Council thought it desirable to ascertain to what extent they might rely upon the co-operation of the Associates in whose interest the question was raised. The Council, however, regret to state that the response made by the Associates to their appeal was such as did not enable them to put the scheme into operation during the year, but the matter is still under consideration.

FINANCIAL POSITION.

In publishing the Statement of Accounts for the past year, the Council are once more in the happy position of being able to congratulate the Society upon the condition of its finances, and to claim that in this most important particular very satisfactory progress is being made. By comparing the income and expenditure with those of the previous year, it will be seen that the former has advanced in spite of very liberal allowances having been made on account of arrears which appeared doubtful. On the expenditure side, increases have occurred on account of Transactions, general printing and visits and dinner, increases involved by the extension and increased efficiency of the Society's work. The net result, as represented by the excess of income over expenditure, although some 20*l.* less than last year, is still very satisfactory and amply justifies the increased expenditure. Even more satisfactory is the total amount of cash on deposit and in hand (388*l.* 5*s.* 4*d.*), which represents the net assets of the Society, apart from all arrears and the value of its furniture, library and stock of Transactions. As regards the last item, it is worthy of remark that our auditor has advised the reduction of the annual allowance for depreciation of furniture on the ground that the actual selling price had almost been reached. Speaking generally, it is a great satisfaction to the Council to be able to make the most liberal allowance for every doubtful asset on the one hand, and to increase expenditure where a direct advantage can be secured on the other, and the fact that this result has been attained without unduly straining our resources is an eloquent testimony to the vitality of our financial position.

PAPERS READ.

During the year the following interesting Papers have been read at the Ordinary Meetings, and these, together with the discussions thereon, will render the forthcoming volume of Transactions no whit behind those which have preceded it.

1. The President's Inaugural Address. By Mr. Charles Mason.
2. Notes on certain Details of Drainage Construction. By Mr. Gerard J. G. Jensen.
3. The Production of Metallic Bars and Tubes under Pressure. By Mr. Perry F. Nursey.

4. The Treatment of Low Grade Iron Ores for the Smelting Furnace. By Mr. Thomas B. Grierson.
5. Concrete Subways for Underground Pipes. By Mr. A. Taylor Allen.
6. Preliminary Investigations for Water Supply. By Mr. Sydney A. Hollis.
7. Irrigation Works in South Africa. By Mr. J. Freebairn Stow.
8. The Main Drainage of Ilford. By Mr. Roger G. Hetherington.
9. The Sewage Question during the Last Century. By Mr. H. Alfred Roechling.

The Council have awarded Premiums to the authors of five of these papers, viz.:—The President's Gold Medal to Mr. H. Alfred Roechling for his paper on "The Sewage Question during the Last Century"; the Bessemer Premium of Books to Mr. Roger G. Hetherington for his paper on "The Main Drainage of Ilford"; a Society's Premium of Books to Mr. Arthur T. Allen for his paper on "Concrete Subways for Underground Pipes"; a Society's Premium of Books to Mr. Sydney A. Hollis for his paper on "Preliminary Investigations for Water Supply"; and a Society's Premium of Books to Mr. J. Freebairn Stow for his paper on "Irrigation Works in South Africa."

Visits to Works.

During the past year three visits to engineering works have been made, and have proved of great interest to the Members and their friends. On June 12, by kind permission of the Directors, a visit was made to the engineering works of Messrs. Fraser and Chalmers at Erith, where a variety of mining, pumping and general machinery was inspected. The air-compressing station of the Shone System of Sewage Ejection, at the same place, was also inspected by kind permission of the local authorities.

On July 18, by kind permission of Messrs. Walter Hunter, and R. E. Middleton, MM.Inst.C.E., the Engineers, and Messrs. John Aird and Co., the Contractors, a visit was made to the works of the Staines Reservoirs in course of construction. At the close of the inspection the visitors were hospitably entertained by Messrs. John Aird and Co. The head of the firm, Sir John Aird, is one of the oldest members of the Society, having been elected in 1855.

On September 25, by kind permission of the Commandant, Major General Sir Thomas Fraser, R.E., a most interesting visit was made to the School of Military Engineering at Chatham. Upon their arrival the visitors were entertained at luncheon at the Royal Engineers' Mess by kind invitation of the Commandant, after which the Royal Engineers' Institute and the Field Park were inspected and a series of highly interesting Military Engineering operations were witnessed, the same having been specially arranged for the occasion.

The Council again take the opportunity of pointing out the great advantages which these visits to Works offer to the junior Members, and of urging them to make it a regular practice to attend them. It is worth recording that to this Society belongs the credit of having initiated in 1862 the now general custom of including visits to Works in the programme of Technical Societies.

Annual Meeting.

The Forty-eighth Annual General Meeting was held at the Society's Offices on Monday, December 9, when the Members of Council and Officers, whose names appear on the first page, were elected by ballot in the usual manner. The Council desire to point out in this connection that while it is found most convenient that nominations for the vacancies occurring on the Council from time to time should emanate from the Council for the time being, any additional nominations made by ordinary Members of the Society always receive the most careful attention, and such nominations are invariably considered before any others in connection with succeeding balloting lists.

Annual Dinner.

The forty-eighth Annual Dinner took place on December 11, at the Hotel Cecil, and was attended by a large number of Members and distinguished guests. A very enjoyable evening was spent, which fully maintained the success of previous functions of a similar character.

Exchange Transactions.

The Society continues to exchange Transactions with the Institutions named in the following list, which are available for the use of the Members and Associates at the Society's Offices:—

The Institution of Civil Engineers.
The Institution of Mechanical Engineers.
The Institution of Electrical Engineers.
The Institution of Naval Architects.
The Iron and Steel Institute.
The Surveyors' Institution.
The Civil and Mechanical Engineers' Society.
The Institution of Junior Engineers.
The Institute of Mining and Metallurgy.
The Royal Engineers' Institute.
The Incorporated Gas Institute.
The Royal Institute of British Architects.
The Society of Arts.
The Liverpool Engineering Society.
The Cleveland Institution of Engineers.
The North East Coast Institution of Engineers and Shipbuilders.
The North of England Institute of Mining and Mechanical Engineers.
The South Wales Institute of Engineers.
The Institution of Engineers and Shipbuilders in Scotland.
The Institution of Civil Engineers of Ireland.
The French Institution of Civil Engineers.
The Canadian Civil Engineers' Society.
The Victorian Institute of Engineers.
The Engineering Association of New South Wales.
The American Society of Civil Engineers.
The Association of Engineering Societies.
The Smithsonian Institution.
The Franklin Institute.

List of Journals and Magazines.

The following publications are supplied gratuitously by their respective Publishers and are also available for reference at the Society's Offices:—

American Machinist.
American Machinery.
Arms and Explosives.
Automotor.
British Architect.
Building News.
Builder.
Commerce.
Colliery Guardian.
Contract Journal.
Cassiers' Magazine.
Electrical Review.
Electrician.
Engineer.
Engineering.
Engineering Magazine.
Engineers' Gazette.
Electro Chemist and Metallurgist.
El Ingeniero Espanol.
Fielden's Magazine.
Invention.
Indian Engineering.
Indian and Eastern Engineer.
Journal of Gas Lighting.
Local Government Journal.
L'Automobile.
Machinery Market.
Marine Engineer.
Mechanical World.
Mechanical Engineer.
Mechanical Progress.
Public Health Engineer.
Railway Official Gazette.
Surveyor.
Sanitary Record.
Shipping World.
Society of Arts Journal.
The Quarry.
The Street.
The Tramway and Railway World.
Water.

Members' Support.

In conclusion, the Council desire to urge upon every Member the desirability of using his best endeavours to promote the interests of the Society at large by regular attendance at all the meetings, by securing as many new Members as possible, and by contributing Papers or taking part in the discussions as opportunity may offer. The younger Members especially are assured that every encouragement will be afforded to them in any effort they may make in this direction, and they are specially invited to submit papers upon subjects of current interest for reading and discussion at the ordinary meetings. Full instructions as to the preparation of papers and a list of suitable subjects can be obtained on application to the Secretary. A form of proposal for a new Member or Associate is enclosed with this Report.

With adequate support from the general body of Members, the Council anticipate no difficulty in not only maintaining the prestige and usefulness of the Society as a whole, but in developing the same to the utmost possible extent.

January, 1902.

Dr. INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1901. Cr

Expenditure.	£	s.	d.	Income.	£	s.	d.
To Printing Transactions, *less* Sales	189	4	4	By Subscriptions for the Year (*less* irrecoverable)	624	15	0
,, Rent of Offices and Hire of Rooms	122	16	0	,, Life Subscriptions—proportion for 1901	9	10	10
,, Salary of Secretary	230	0	0	,, Admission Fees	61	8	6
,, Stationery and General Printing	37	4	5	,, Interest on Investment and Deposit	13	6	9
,, Reporting Meetings	14	14	0				
,, Refreshments for Members at Ordinary Meetings	5	8	4				
,, Fuel, Lighting, Office Cleaning and Repairs	14	10	6				
,, Postage, Telegrams, Carriage, and General Expenses	47	18	5				
,, Depreciation on Furniture	4	3	0				
,, Vacation Visits and Dinner—deficiency	9	17	10				
	675	16	10				
,, Balance carried to Accumulated Fund— Excess of Income over Expenditure for the year ended 31st December, 1901	33	4	3				
	£709	1	1		£709	1	1

LIFE MEMBERSHIP FUND.

	£	s.	d.		£	s.	d.
To Revenue Account—proportion for the year 1901	9	10	10	By Balance, being the unexhausted Balance of the Fund on 31st December, 1900	95	8	4
,, Balance to be carried to next Account	85	17	6				
	£95	8	4		£95	8	4

PREMIUM FUND.

	£	s.	d.		£	s.	d.
To Premiums	14	0	0	By Balance brought forward from 31st December, 1900	16	13	6
,, Balance to be carried to next Account	18	8	3	,, President's Donation	10	10	0
				,, Interest received from "Bessemer Trust" Investment	5	4	9
	£32	8	3		£32	8	3

BALANCE SHEET, 31st DECEMBER, 1901.

LIABILITIES.

				£	s.	d.
Sundry Creditors				9	1	11
Life Membership Fund				85	17	6
Premium Fund..				18	8	3
Subscriptions Paid in Advance..				36	4	6
Accumulated Fund;—						
Balance at 31st December, 1900 ..	£610	15	7			
Add Excess of Income over Expenditure for the year ended 31st December, 1901	33	4	3	643	19	10
				£793	12	0

ASSETS.

				£	s.	d.
Subscriptions in Arrears	£135	11	6			
Admission Fees in Arrear	8	8	0			
	143	19	6			
Less reserved for Bad Debts ..	50	0	0			
				93	19	6
Cash at Bank	35	9	7			
Cash in Hand	2	15	9			
				38	5	4
Cash on Deposit	£350	0	0			
Investment—£166 L. & N. W. Ry. Co. 3 per cent. Debenture Stock (cost)	199	5	8			
				549	5	8
Office Furniture, Library and Stock of Transactions				112	1	6
				£793	12	0

Note.—£185 North Eastern Railway Stock is held in Trust to secure payment of the late Sir Henry Bessemer's Premium.

Audited and found correct,

(Signed) SAML. WOOD, *Hon. Auditor*,
30 Gracechurch Street,
London, E.C.

8*th January*, 1902.

SOCIETY OF ENGINEERS.

INDEX TO TRANSACTIONS

1857 to 1901.

AUTHORS.

Author.	Subject of Paper.	Transactions	
		Year.	Page.
Abel, C. D.	The Patent Laws	1865	25
Adams, H.	President's Address	1890	1
Adams, J. H.	President's Address	1875	1
Adams, T.	The Friction of the Slide-valve, and its Appendages.	1866	6
Adams, W.	President's Address	1870	1
Alford, C. J.	The Mineralogy of the Island of Sardinia.	1879	93
„ „	Appendix to Above: Laws relating to Mining.	1879	106
„ „	Engineering Notes on Cyprus	1880	131
Alford, R. F.	The Fell Engines on the Rimutakai Incline, New Zealand.	1882	121
Allan, G. W.	Marine Insurance	1858	14
Allanson-Winn, R. G.	Foreshore Protection, with special reference to the Case System of Groyning	1899	133
Allen, A. T.	Concrete Subways for Underground Pipes.	1901	99
Amos, E. C.	Machine Tools	1899	51
Amos, James	The Machinery employed in laying the Atlantic Cable.	1858	13
„ „	The New Hydraulic Machinery for lifting Vessels in the Thames Graving Dock.	1859	17
Anderson, Chris.	The Feasibility and Construction of Deep-sea Lighthouses.	1883	45
André, G. G.	The Ventilation of Coal Mines	1874	28
„ „	The Application of Electricity to the Ignition of Blasting Charges.	1878	123
Andrews, J. J. F.	Ship Caissons for Dock Basins and Dry Docks.	1890	189
Andrews, T.	The Strength of Wrought-iron Railway Axles.	1879	143
„ „	The Effect of Strain on Railway Axles, and the Minimum Flexion Resistance-Point in Axles.	1895	181
Ansell, W.	The Electric Telegraph	1857	11
Atkinson, J.	Apparatus for Utilising the Waste Heat of Exhaust Steam.	1878	167
Ault, E.	The Shone Hydro-Pneumatic Sewerage System.	1887	63
Baillie, J. R.	President's Address	1889	1
Baker, T. W.	The Utilisation of Town Refuse for generating Steam.	1894	183

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Baldwin, T.	Single and Double Riveted Joints ..	1866	150
,, ,, ...	Experimental Researches into the Nature and Action of Safety Valves for Steam Boilers, &c.	1867	23
Bamber, H. K.	Water, and its Effects on Steam Boilers	1867	65
Bancroft, R. M. ..	Renewal of Roof over Departure Platform at King's Cross Term., G.N.R.	1887	125
Barber, J. P.	Notes on the Proposed By-laws of the London County Council with respect to House Drainage.	1897	17
Barker, C. M.	The Prevention of Leakage in Gas and Water Mains.	1869	79
Barker, E. D.	Hydraulic Continuous and Automatic Brakes.	1879	75
Barker, Capt. W. B.	International System of Marine Course Signalling.	1884	47
Barnett, S.	The Value of Exhibitions as Aids to Engineering Progress.	1883	75
Bartholomew, E. G.	Electric Telegraphy, irrespective of Telegraphic Apparatus.	1869	55
,, ,,	Electric Telegraph Instruments ..	1872	53
,, ,,	Electrical Batteries	1872	77
Beaumont, W. W. ..	President's Address	1898	1
,, ,, ..	Modern Steel as a Structural Material	1880	109
,, ,, ..	High Pressure Steam and Steam-engine Efficiency.	1888	221
Beaumont, W. W., and Sellon, S.	Notes on Parliamentary Procedure as affecting Light Railways & Tramways.	1895	33
Behr, F. B.	The Lartigue Single-rail Railway ..	1886	163
Bellasis, E. S.	The Roorkee Hydraulic Experiments	1886	41
Bernays, J.	President's Address	1880	1
,, ,, ...	The New Pits and Hauling Machinery for the San Domingos Mines in Portugal.	1879	29
Biggs, C. H. W., and Beaumont, W. W.	Notes on Electric Light Engineering	1882	23
Binyon, A. H.	Notes on Electric Traction	1900	103
Björling, P. B.	Direct-acting Pumping Engines ..	1877	79
Blackbourn, J.	The Action of Marine Worms, and Remedies applied in the Harbour of San Francisco.	1874	111
Bolton, R.	The Application of Electricity to Hoisting Machinery.	1892	79
Bower, G.	The Preservation and Ornamentation of Iron and Steel Surfaces.	1883	59
Bowers, George ..	The Permanent Way of Railways ..	1857	11
Boyd, R. N.	Collieries and Colliery Engineering ..	1893	169
,, ,, ...	A Deep Boring near Freistadt, Austria, by the Canadian System.	1894	119
Brigg, T. H.	The Mechanics of Horse Haulage ..	1896	21
Brothers, W. H. ..	Weighing Machinery and Automatic Apparatus in connection therewith.	1890	55
Browning, C. E. ..	The Strength of Suspension Bridges ...	1858	11

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Browning, C. E.	The Extension and Permanent Set of Wrought Iron.	1858	15
Bryant, F. W.	Piling and Coffer Dams	1859	38
" "	President's Address	1869	1
Buckham, T.	The Drainage and Water Supply to the Town of Fareham.	1869	41
Burrows, E.	Blake's Bridge, Reading	1893	71
Butler, D. B.	Portland Cement, some Points in its Testing, Uses and Abuses.	1895	61
" "	The Effect of Admixtures of Kentish Ragstone, &c., upon Portland Cement.	1896	179
Carey, R.	Hydraulic Lifts	1893	101
Cargill, T.	President's Address	1877	1
" "	Railway Bridge at the Place de l'Europe, Paris.	1866	191
" "	Floating Breakwaters	1871	146
Carpenter, C. C.	Modern Coal Gas Manufacture	1891	61
Carrington, W. T.	Generation and Expansion of Steam	1858	15
" "	Pumping Engines	1859	19
" "	President's Address	1865	1
Carter, J. H.	Roller-milling Machinery	1883	125
Cheesewright, F. H.	Breakwater Construction	1890	83
Church, Jabez	President's Address	1872	1
" "	President's Address	1873	1
Church, Jabez, jun.	President's Address	1882	1
" "	President's Address	1883	1
Colam, W. N.	Cable Tramways	1885	69
" "	President's Address	1891	1
Colburn, Zerah	President's Address	1866	1
" "	The Relation between the Safe Load and Ultimate Strength of Iron.	1863	35
" "	Certain Methods of Treating Cast Iron in the Foundry.	1865	77
Conradi, H.	Stone-sawing Machinery	1876	135
" "	Cleaning of Tramway, and other Rails.	1893	47
Copland, H. S.	Modern Roadway Construction	1878	61
Cowper-Coles, S. O.	Protective Metallic Coatings for Iron and Steel.	1898	139
" "	The Electrolytic Treatment of Complex Sulphide Ores	1899	203
Cox, S. H.	Recent Improvements in Tin-dressing Machinery.	1874	11
" "	Dry Crushing Machinery	1892	101
" "	President's Address	1896	1
Cramp, C. C.	Tramway Rolling-stock and Steam in connection therewith	1874	119
Crimp, W. S.	The Wimbledon Main Drainage and Sewage Disposal Works.	1888	73
" "	Sewer Ventilation	1890	139
Croll, J.	Filter Presses for Sewage Sludge	1897	121

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
CROMPTON, E. S.	The Economics of Railway Maintenance.	1870	101
CULLEN, DR. E.	The Surveys of Proposed Lines for a Ship Canal between the Atlantic and Pacific Oceans.	1868	15
” ”	The Panama Railroad	1868	39
” ”	Isthmus of Darien and the Ship Canal	1868	52
CUNNINGHAM, J. H.	Pin-connected *v.* Riveted Bridges	1889	135
DANVERS, F. C.	Engineering in India	1868	137
DAVENPORT, J. G.	Wooden Jetties on the River Thames and their Improvement of the Inshore Navigation.	1859	24
DAVEY, H.	Pumping Engines for Town Water-supply.	1867	88
” ”	Milford Haven and its New Pier Work.	1872	89
” ”	Recent Improvements in Pumping Engines for Mines.	1873	182
” ”	The Underground Pumping Machinery at the Erin Colliery, Westphalia.	1876	119
DAY, ST. J. V.	Recent Arrangements of Continuous Brakes.	1875	87
DE SEGUNDO, E. C.	Power Distribution by Electricity, Water and Gas.	1894	143
DRURY, A. G.	The Shortlands and Nunhead Railway	1892	219
EDWARDS, E.	Mining Machinery	1859	35
” ”	Utilization of Waste Mineral Substances.	1861	82
ENGERT, A. C.	The Prevention of Smoke	1881	101
” ”	Defects of Steam Boilers and their Remedy.	1884	25
” ”	The Blow-pipe Flame Furnace	1884	185
FAIJA, H.	Portland Cement	1885	95
” ”	The Effect of Sea Water on Portland Cement.	1888	39
” ”	Forced Filtration of Water through Concrete.	1889	107
FARADAY, P. M.	The Rating of Engineering Undertakings.	1897	43
FELL, J. C.	President's Address	1899	1
” ”	Soft *v.* Hard Water for Manufacturing Purposes.	1884	103
FERRAR, W. G.	Practical Construction in the Colonies	1875	53
FOX, ST. G. LANE	The Lighting and Extinction of Street Gas Lamps by Electricity.	1878	105
FOX, W.	Reservoir Embankments	1898	23
FOX, W. H.	Continuous Railway Brakes	1872	112

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Fox, W. H.	Continuous Railway Brakes	1873	33
Fraser, A.	Use of the Cornish Pumping Engine ..	1864	78
Gandon, C.	President's Address	1885	1
" "	Gas Engines	1881	27
Gibbs. J. D.	The Distribution of Electrical Energy by Secondary Generators.	1885	49
Glynn, J., Junr.	Softening Water by Dr. Clarke's Process.	1859	29
" "	The Chalk Formation	1860	46
Goodwin, G. A.	President's Address	1894	1
Gore, H.	Modern Gas Works at Home and Abroad.	1868	233
" "	Horse Railways and Street Tramways	1873	113
Graham, J.	The most Recent Improvements on the Injector.	1867	266
Grantham, R. F. ..	Sea Defences	1897	143
" " ..	The Closing of Breaches in Sea and River Embankments.	1900	21
Greig, A.	Dundee Street Improvements and Drainage of Lochee.	1883	113
Gresham, J.	The most Recent Improvements on the Injector.	1867	266
Grierson, F. W. ..	The National Value of Cheap Patents	1880	145
Grierson, T. B.	The Treatment of Low-grade Iron Ores for the Smelting Furnace.	1901	69
Griffin, S.	Modern Gas-Engine Practice	1889	169
Griffith, P.	The Treatment and Utilisation of Exhaust Steam.	1890	163
" "	The Water Supply of Small Towns and Rural Districts.	1896	55
Hakewill, H.	Circular Tables	1865	147
Hall, C. E.	The Conversion of Peat into Fuel and Charcoal.	1876	151
" "	Modern Machinery for Preparing Macadam for Roads.	1879	51
Harman, E. A.	Gas-Works Machinery	1898	97
Harris, G.	Water Supply to Country Mansions and Estates	1899	231
Hartley, F. W. ..	Methods employed in the Determination of the Commercial Value and the Purity of Coal Gas.	1869	100
" "	An Improved Method of Charging and Drawing Gas Retorts.	1875	185
Healey, B. D.	The Economical Disposal of Town Refuse.	1900	65
Henderson, R.	Paper-Making Machinery	1900	139
Hendry, J.	Pump Valves	1859	25
Hetherington, R. G.	The Main Drainage of Ilford	1901	173

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Hollis, S. A.	Preliminary Investigations for Water Supply.	1901	147
Holttum, W. H.	The Use of Steel Needles in Driving a Tunnel at King's Cross.	1892	199
Hooper, H. R.	The Practice of Foundry Work	1888	191
Horner, J. G.	Certain Methods of Applying Screw Piles in a Bridge at Verona.	1867	52
Horsley, C.	President's Address	1881	1
Hutton, R. J.	The Stability of Chimney Shafts	1887	150
Jacob, A.	The Designing and Construction of Storage Reservoirs.	1866	225
Jensen, G. J. G.	Notes on Certain Details of Drainage Construction.	1901	19
Jensen, P.	Incrustation in Marine Boilers	1866	117
,, ,,	Friction in Steam Cylinders	1870	17
Jerram, G. B.	River Pollution caused by Sewage Disposal.	1886	217
Jones, A. W.	Modern Tramway Construction	1879	179
Justice, P. S.	The Dephosphorisation of Iron in the Puddling Furnace.	1885	189
Kerr, J.	Portable and Pioneer Railways	1891	89
Kershaw, J. T.	Breakwaters and Harbours of Refuge	1859	31
,, ,,	The Pipe Sewers of Croydon and the Causes of their Failure.	1860	52
King, G.	Irrigation with Town Sewage	1865	84
Kinsey, W. B.	The Arrangement, Construction, and Machinery of Breweries.	1881	173
Knapp, H. F.	Harbour Bars: their Formation and Removal.	1878	139
Kochs, W. E.	Strength and Rigidity	1865	69
Lailey, C. N.	Acton Main Drainage Works	1888	125
Latham, B.	President's Address	1868	1
,, ,,	President's Address	1871	1
,, ,,	The Drainage of the Fens	1862	125
,, ,,	The Inundations of Marsh Lands	1862	173
,, ,,	The Supply of Water to Towns	1864	199
,, ,,	Utilization of Sewage	1866	68
,, ,,	The Application of Steam to the Cultivation of the Soil.	1868	274
,, ,,	Ventilation of Sewers	1871	39
Lawford, G. M.	President's Address	1897	1
,, ,,	Fireproof Floors	1889	43
,, ,,	Drainage of Town Houses	1891	187
Lawford, W.	Light Railways	1888	181
Lee, J. B.	Photographic Surveying	1899	171
Le Feuvre, W. H.	President's Address	1867	1
Le Grand, A.	Tube Wells	1877	133

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
LEWES, V. B.	Gas Substitutes	1893	141
LIGHT, C. J...	Railway Switches and Crossings ..	1857	13
,, ,, ...	Railway Turntables	1858	11
,, ,, ...	The Permanent Way of Railways ..	1859	21
,, ,, ...	The Need of further Experiments on the Strength of Materials.	1869	194
,, ,, ...	A new Method of setting-out the Slopes of Earthworks.	1873	216
,, ,, ...	Opening Bridges on the Furness Railway.	1885	119
LIGHT, C. L.	Street Railways	1860	56
LIGHTFOOT, T. B. ..	Refrigerating Machinery on Board Ship.	1887	105
,, ,, ...	A Trial of a Refrigerating Machine on the Linde System.	1891	39
LOUCH, J.	Surface Condensers	1861	96
MACGEORGE, W.	President's Address	1874	1
MAJOR, W.	The Priming of Steam-Boilers	1877	59
MARTIN, W.	The Strength of Flues in Lancashire and similar Boilers.	1882	157
MARTIN, W. A.	Induced *v.* Forced Draught for Marine Boilers.	1886	111
MASON, C.	President's Address	1901	1
,, ...	Street Subways for Large Towns ..	1895	91
MATHESON, E.	The Quality of Iron, as now used ..	1867	168
,, ,, ...	The Accumulator Cotton Press	1868	264
MAUDE, T.	The Government Brake Trials	1875	129
MAWBEY, E. G.	The Leicester Main Drainage	1893	25
MCNAUGHT, W.	The Rolling of Ships	1876	187
MIDDLETON, R. E. ..	The Relative Value of Percolation Gauges.	1895	153
,, ,, ..	The Pollution of Water and its Correction.	1897	173
MILES, W. P.	Locks and Fastenings	1860	26
MILLER, B. A.	The Cleansing and Ventilation of Pipe Sewers.	1892	167
MOLESWORTH, G. L. ..	The Utilisation of Water Power ..	1858	16
MOORE, L. G.	The Explosion at Erith, and the Repair of the River Bank.	1864	183
MORRIS, W.	The Machinery employed in raising Water from an Artesian Well.	1860	29
MOULTRIE, F. R. ..	Photography	1857	12
NURSEY, P. F.	President's Address	1886	1
,, ,, ...	Quartz Crushing Machinery .. .	1860	17
,, ,, ...	The Chemical Extraction of Gold from its Ores.	1860	42
,, ,, ...	The Superheating of Steam, and the various Apparatus employed therein	1861	36
,, ,, ...	Steam Boiler Explosions	1863	1

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
NURSEY, P. F.	Fuel	1864	1
,, ,,	Sugar-making Machinery	1865	155
,, ,,	Explosive Compounds for Engineering Purposes.	1869	10
,, ,,	English and Continental Intercommunication.	1869	154
,, ,,	Recent Improvements in Explosive Compounds.	1871	108
,, ,,	Economic Uses of Blast Furnace Slag	1873	196
,, ,,	Mechanical Puddling	1874	77
,, ,,	The Channel Railway	1876	17
,, ,,	Illumination by means of Compressed Gas.	1881	57
,, ,,	Modern Bronze Alloys for Engineering Purposes.	1884	127
,, ,,	Primary Batteries for Illuminating Purposes.	1887	185
,, ,,	Recent Developments in High Explosives.	1889	71
,, ,,	Fox's Patent System of Solid-pressed Steel Waggon and Carriage Frames.	1889	197
,, ,,	Pick's System of Manufacturing Salt in Vacuo.	1890	115
,, ,,	Some Practical Examples of Blasting	1893	201
,, ,,	The Preparation of Rhea Fibre for Textile Purposes.	1898	177
,, ,,	The Production of Metallic Bars and Tubes under Pressure.	1901	45
OATES, A.	The Utilisation of Tidal Energy	1882	81
O'CONNOR, H.	President's Address	1900	1
,, ,,	Machine Stokers for Gas Retorts	1891	117
,, ,,	Pile-Driving	1894	71
,, ,,	Automatic Gas Station Governors	1897	67
OLANDER, E.	The Enclosure of Lands from the Sea, and the Construction of Sea and other Banks.	1862	25
,, ,,	Bridge Floors: Their Design, Strength, and Cost.	1887	27
OLRICK, H.	A new System of Treating Sewage Matter.	1883	23
OLRICK, L.	Marine Governors	1862	104
,, ,,	Giffard's Injector	1865	280
ORDISH, R. M.	Suspension Bridges	1857	13
,, ,,	The Forms and Strengths of Beams, Girders and Trusses.	1858	13
PAGE, G. G.	The Construction of Chelsea Bridge	1863	77
PARKES, M.	The Road Bridges of the Charing Cross Railway.	1864	143

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Parkes, M.	The Charing Cross Railway Bridge over the Thames.	1864	166
Parsey, W.	Perspective	1859	26
,, ,,	Trussed Beams	1862	52
Paul, J. H.	Corrosion in Steam Boilers	1891	147
Pearse, J. W.	The Ventilation of Buildings	1876	97
,, ,,	The Mechanical Firing of Steam Boilers.	1877	31
,, ,,	Water Purification, Sanitary and Industrial.	1878	29
Pease, E. L.	Gasholder Construction	1894	95
Peirce, W. G.	President's Address	1895	1
Pendred, H. W.	Screw Propellers, their Shafts and Fittings.	1875	151
,, ,,	Distilling and Hoisting Machinery for Sea-going Vessels.	1880	55
,, ,,	Designs, Specifications, and Inspection of Ironwork.	1883	87
Pendred, V.	President's Address	1876	1
,, ,,	Elastic Railway Wheels	1864	119
,, ,,	The Adhesion of Locomotive Engines, and certain Expedients for increasing or supplementing that Function.	1865	207
,, ,,	Water-tube Boilers	1867	109
,, ,,	Apparatus for Measuring the Velocity of Ships.	1869	215
,, ,,	Examples of Recent Practice in American Locomotive Engineering.	1872	19
Perrett, E.	Filtration by Machinery	1888	106
Phillips, J.	The Forms and Construction of Channels for the Conveyance of Sewage.	1874	145
Pieper, C.	Ice-making Machinery	1882	139
Pollard-Urquhart, M. A.	Examples of Railway Bridges for Branch Lines.	1896	117
Ransom, H. B.	The Principles and Practice of Hydro-Extraction.	1894	227
Reade, S. A.	The Redhill Sewage Works	1868	168
Redman, J. B.	Tidal Approaches and Deep Water Entrances.	1885	143
Rigg, A.	President's Address	1884	1
,, ,,	The Connection between the Shape of heavy Guns and their Durability.	1867	249
,, ,,	The Screw Propeller	1868	202
,, ,,	Sensitiveness and Isochronism in Governors.	1880	73
,, ,,	American Engineering Enterprise	1885	21
,, ,,	Obscure Influences of Reciprocation in High-speed Engines.	1886	83
,, ,,	Balancing of High-speed Steam Engines.	1891	23
,, ,,	Hydraulic Rotative Engines	1896	89

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Riley, E.	The Manufacture of Iron	1861	59
” ”	The Action of Peaty Water on a Boiler	1862	45
Roberts, W.	Steam Fire-engines, and the late Trials at the Crystal Palace.	1863	163
Robertson, George	Mortars and Cements	1857	11
Robinson, H.	President's Address	1887	1
” ”	Sewage Disposal	1879	197
Roechling, H. A.	The Sewage Question during the last Century.	1901	193
Roots, J. D.	Petroleum Motor Vehicles	1899	95
Rous-Marten, C.	Notes on English and French Compound Locomotives.	1900	173
Rumble, T. W.	Armour Plates	1861	87
Rymer-Jones, T. M.	Railway Tunnelling in Japan	1882	101
Sanderson, C.	The Bombay, Baroda, and Central India Railway.	1863	97
Schönheyder, W.	Equalising the Wear in Horizontal Steam Cylinders.	1878	45
Sefi, M.	The Theory of Screw Propulsion	1870	82
Sellon, S.	Electrical Traction and its Financial Aspect.	1892	37
Sellon, S., and Beaumont, W. W.	Notes on Parliamentary Procedure as affecting Light Railways and Tramways.	1895	33
Shenton, H. C. H.	Recent Practice in Sewage Disposal	1900	217
Somerville, J.	Charging and Drawing Gas Retorts by Machinery.	1873	138
Spencer, G.	State Railways and Railway Amalgamation.	1872	43
Spice, R. P.	President's Address	1878	1
” ”	President's Address	1879	1
” ”	Some Modern Improvements in the Manufacture of Coal Gas.	1886	131
Spon, E.	The Use of Paints as an Engineering Material.	1875	69
Standfield, J.	Floating Docks—the Depositing Dock, and the Double-power Dock.	1881	81
Steel, J.	Air Compression	1876	65
Stephenson, H. P.	Screw Piles	1857	12
Stephenson, W. H.	The General Structure of the Earth	1858	12
” ”	Fire-clay Manufactures	1861	17
Stocker, C. W.	Diving Apparatus	1860	32
Stopes, H.	The Engineering of Malting	1884	65
Stow, J. F.	Irrigation Works in South Africa	1901	159
Strachan, G. R.	The Construction and Repair of Roads	1889	17
Suckling, N. J.	Modern Systems of Generating Steam	1874	39
Sugg, W. T.	Apparatus employed for Illumination with Coal Gas.	1869	134
” ”	Ventilation and Warming	1895	235
Sutcliff, R.	Tube Wells for large Water Supplies	1877	149

Author.	Subject of Paper.	Transactions.	
		Year.	Page.
Tarbutt, P. F.	Liquid Fuel	1886	193
Thresh, J. C.	The Protection of Underground Water Supplies.	1898	47
Thrupp, E. C.	A New Formula for the Flow of Water in Pipes and Open Channels.	1887	224
Thudichum, G.	The Ultimate Purification of Sewage	1896	199
,, ,,	Bacterial Treatment of Sewage	1898	207
Trewman, H. C.	Flues and Ventilation	1876	91
Turner C.	The Timbering of Trenches and Tunnels.	1871	90
Tweddell, R. H.	Direct-Acting Hydraulic Machinery	1877	95
,, ,,	The Application of Water Pressure to Machine Tools and Appliances.	1890	35
Umney, H. W.	Safety Appliances for Elevators	1895	113
,, ,,	The Compression of Air by the Direct Action of Water.	1897	93
Usill, G. W.	Rural Sanitation	1877	113
Valon, W. A. M.	President's Address	1893	1
Varley, S. A.	Railway Train Intercommunication	1873	162
Wagstaff, E. W.	The Shan Hill Country and the Mandalay Railway	1899	21
Wales, W. G.	Discharging and Storing Grain	1896	149
Walker, J.	Brewing Apparatus	1871	29
Walmisley, A. T.	President's Address	1888	1
,, ,,	Iron Roofs	1881	123
Wanklyn, J. A.	Cooper's Coal-liming Process	1884	167
Ward, G. M.	The Utilisation of Coal Slack in the Manufacture of Coke for Smelting.	1880	33
Ware, W. J., and Woodhead, G. S.	Disinfection of the Maidstone Water Service Mains.	1900	49
Warren, A.	Steam Navigation on the Indus	1863	139
Wessely, C. R. von	Arched Roofs	1866	36
Wilkins, T.	The Machinery and Utensils of a Brewery.	1871	10
Willcock, J.	Gas Meters and Pressure Gauges	1860	37
Wilson, A. F.	The Manufacture of Coal Gas	1864	35
Wilson, J. W.	The Construction of Modern Piers	1875	29
,, ,,	President's Address	1892	1
Wise, F.	Signalling for Land or Naval Purposes.	1863	117
Wise, W. L.	The Patent Laws	1870	45
Wollheim, A.	Foreign Sewage Precipitation Works	1892	123
Woodhead, G. S., and Ware, W. J.	Disinfection of the Maidstone Water Service Mains.	1900	49
Worssam, S. W.	Mechanical Saws	1867	196
Yarrow, A. F.	Steam Carriages	1862	128
Young, C F. T.	The Use of Coal in Furnaces without Smoke.	1862	66

SUBJECTS.

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Accumulator Cotton Press	E. Matheson	1868	264
Action of Marine Worms and Remedies employed in Harbour of San Francisco.	J. Blackbourn	1874	111
Action of Peaty Water on a Boiler	E. Riley	1862	45
Acton Main Drainage Works	C. N. Lailey	1888	125
Address of President	W. T. Carrington	1865	1
,, ,,	Z. Colburn	1866	1
,, ,,	W. H. Le Feuvre	1867	1
,, ,,	B. Latham	1868	1
,, ,,	F. W. Bryant	1869	1
,, ,,	W. Adams	1870	1
,, ,,	B. Latham	1871	1
,, ,,	J. Church	1872	1
,, ,,	,, ,,	1873	1
,, ,,	W. Macgeorge	1874	1
,, ,,	J. H. Adams	1875	1
,, ,,	V. Pendred	1876	1
,, ,,	T. Cargill	1877	1
,, ,,	R. P. Spice	1878	1
,, ,,	,, ,,	1879	1
,, ,,	J. Bernays	1880	1
,, ,,	C. Horsley	1881	1
,, ,,	J. Church	1882	1
,, ,,	,, ,,	1883	1
,, ,,	A. Rigg	1884	1
,, ,,	C. Gandon	1885	1
,, ,,	P. F. Nursey	1886	1
,, ,,	Professor H. Robinson	1887	1
,, ,,	A. T. Walmisley	1888	1
,, ,,	J. R. Baillie	1889	1
,, ,,	H. Adams	1890	1
,, ,,	W. N. Colam	1891	1
,, ,,	J. W. Wilson	1892	1
,, ,,	W. A. M. Valon	1893	1
,, ,,	G. A. Goodwin	1894	1
,, ,,	W. G. Peirce	1895	1
,, ,,	S. H. Cox	1896	1
,, ,,	G. M. Lawford	1897	1
,, ,,	W. W. Beaumont	1898	1
,, ,,	J. C. Fell	1899	1
,, ,,	H. O'Connor	1900	1
,, ,,	C. Mason	1901	1
Adhesion of Locomotive Engines and certain Expedients for Increasing or Supplementing that Function.	V. Pendred	1865	207
Admixtures of Kentish Ragstone, &c., upon Portland Cement, The Effect of	D. B. Butler	1896	179

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Air Compression	J. Steel	1876	65
Air, Compression of, by the Direct Action of Water, The.	H. W. Umney	1897	93
American Engineering Enterprise	A. Rigg	1885	21
American Locomotive Engineering, Examples of recent Practice in	V. Pendred	1872	19
Apparatus for utilising the Waste Heat of Exhaust Steam.	J. Atkinson	1878	167
Apparatus for Measuring the Velocity of Ships.	V. Pendred	1869	15
Apparatus employed for Illumination with Coal Gas.	W. Sugg	1869	134
Application of Electricity to Hoisting Machinery.	R. Bolton	1892	79
Application of Steam to the Cultivation of the Soil.	B. Latham	1868	274
Application of Water Pressure to Machine Tools and Appliances.	R. H. Tweddell	1890	35
Arched Roofs	C. von Wessely	1866	36
Armour Plates	T. W. Rumble	1861	87
Arrangement, Construction, and Machinery of Breweries.	W. B. Kinsey	1881	173
Artesian Well, The Machinery employed in raising Water from an	W. Morris	1860	29
Atlantic Cable, The Machinery employed in laying the	J. Amos	1858	13
Automatic Gas Station Governors	H. O'Connor	1897	67
Axles, The Strength of Wrought-iron Railway	T. Andrews	1879	143
Bacterial Treatment of Sewage	G. Thudichum	1898	207
Bars and Tubes, The Production of Metallic, under Pressure.	P. F. Nursey	1901	45
Batteries, Primary, for Illuminating Purposes.	P. F. Nursey	1887	185
Beams, Girders and Trusses, The Forms and Strengths of	R. M. Ordish	1858	13
Blake's Bridge, Reading	E. Burrows	1893	71
Blast-furnace Slag, The Economic Uses of	„ „	1873	196
Blasting Charges, The Application of Electricity to the Ignition of	G. G. André	1878	123
Blasting, Some Practical Examples of	P. F. Nursey	1893	201
Blow-pipe Flame Furnace	A. C. Engert	1884	185
Boilers, Incrustation in Marine	P. Jensen	1866	117
Boilers, Strength of Flues in Lancashire and similar	W. Martin	1882	157
Boilers, The Defects of Steam, and their Remedy.	A. C. Engert	1884	25
Boilers, The Mechanical Firing of Steam	J. W. Pearse	1877	31
Boilers, The Priming of Steam	W. Major	1877	59
Boilers, Water and its Effects on Steam	H. K. Bamber	1867	65

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Boilers, Water Tube	V. Pendred	1867	109
Bombay, Baroda, and Central India Railway.	C. Sanderson	1863	97
Brake Trials, The Government	T. Maude	1875	129
Brakes, Continuous Railway	W. H. Fox	1872	112
” ”	” ”	1873	33
Brakes, Hydraulic Continuous and Automatic	E. D. Barker	1879	75
Brakes, Recent Arrangements of Continuous	St. J. V. Day	1875	87
Breaches in Sea and River Embankments, The Closing of.	R. F. Grantham	1900	21
Breakwater Construction	F. H. Cheesewright	1890	83
Breakwaters and Harbours of Refuge	J T. Kershaw	1859	31
Breakwaters, Floating	T. Cargill	1871	146
Breweries, the Arrangement, Construction, and Machinery of	W. B. Kinsey	1881	173
Brewery, Machinery and Utensils of a	T. Wilkins	1871	10
Brewing Apparatus	J. Walker	1871	29
Bridge, Blake's, Reading	E. Burrows	1893	71
Bridge, Railway, at the Place de l'Europe, Paris	T. Cargill	1866	191
Bridge Floors: Their Design, Strength and Cost.	E. Olander	1887	27
Bridge, Construction of Chelsea	G. G. Page	1863	77
Bridge over the Thames, Charing Cross Railway	M. Parkes	1864	166
Bridges of the Charing Cross Railway, The Road	M. Parkes	1864	143
Bridges, Opening, on Furness Railway	C. J. Light	1885	119
Bridges, The Strength of Suspension	C. E. Browning	1858	11
Bridges, Suspension	R. M. Ordish	1857	13
Bronze Alloys for Engineering Purposes, Modern	P. F. Nursey	1884	127
Buildings, The Ventilation of	J. W. Pearse	1876	97
Cable Tramways	W. N. Colam	1885	69
Caissons, Ship, for Dock Basins and Dry Docks.	J. J. F. Andrews	1890	189
Canadian System, A deep Boring near Freistadt, Austria, by the	R. N. Boyd	1894	119
Canal between the Atlantic and Pacific Oceans, The Surveys of Proposed Lines for a Ship	Dr. E. Cullen	1868	15
Canal, The Isthmus of Darien and the Ship	” ”	1868	52
Carriage Frames, Fox's Patent System of Solid pressed Steel Waggon and	P. F. Nursey	1889	197
Carriages, Steam	A. F. Yarrow	1862	128
Case System of Groyning, Foreshore Protection, with special reference to the	R. G. Allanson-Winn	1899	133
Cast-iron, Certain Methods of Treating, in the Foundry.	Z. Colburn	1865	77

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Cement, Portland	H. Faija	1885	95
Cements, Mortars and	G. Robertson	1857	11
Central India Railway, Bombay, Baroda, and	C. Sanderson	1863	97
Chalk Formation, The	J. Glynn, Junr.	1860	46
Channel Railway, The	P. F. Nursey	1876	17
Channels for the Conveyance of Sewage, The Forms and Construction of	J. Phillips	1874	145
Charcoal, The Conversion of Peat into Fuel and	C. E. Hall	1876	151
Charging and Drawing Gas Retorts by Machinery.	J. Somerville	1873	138
Charging and Drawing Gas Retorts, An Improved Method of	F. W. Hartley	1875	185
Charing Cross Railway Bridge over the Thames.	M. Parkes	1864	166
Charing Cross Railway, The Road Bridges of	„ „	1864	143
Cheap Patents, The National Value of	F. W. Grierson	1889	145
Chelsea Bridge, The Construction of	G. G. Page	1863	77
Chimney Shafts, Stability of	R. J. Hutton	1887	150
Circular Tables	H. Hakewill	1865	147
Cleansing and Ventilation of Pipe Sewers.	B. A. Miller	1892	167
Cleaning of Tramway and other Rails	H. Conradi	1893	47
Coal Gas, The methods employed in the determination of the Commercial Value and Purity of	F. W. Hartley	1869	100
Coal Gas, Apparatus employed for illumination with	W. Sugg	1869	134
Coal Gas, The Manufacture of	A. F. Wilson	1864	35
Coal Gas, Modern Manufacture of	C. C. Carpenter	1891	61
Coal Gas, Some Modern Improvements in the Manufacture of	R. P. Spice	1886	131
Coal-liming Process, Cooper's	J. A. Wanklyn	1884	137
Coal Mines, The Ventilation of	G. André	1874	23
Coal Slack, Utilisation of, in the Manufacture of Coke for Smelting.	G. M. Ward	1880	33
Coffer Dams, Piling and	F. W. Bryant	1859	38
Collieries and Colliery Engineering	R. N. Boyd	1893	169
Colliery, The Underground Pumping Machinery at the Erin, Westphalia.	H. Davey	1876	119
Colonies, Practical Construction in the	W. G. Ferrar	1875	53
Compressed Gas, Illumination by means of	P. F. Nursey	1881	57
Compression, Air	J. Steel	1876	65
Compression of Air by the Direct Action of Water, The.	H. W. Umney	1897	93
Concrete, Forced Filtration of Water Through	H. Faija	1889	107
Concrete Subways for Underground Pipes.	A. T. Allen	1901	99
Condensers, Surface	J. Louch	1861	96

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Connection between the Shape of Heavy Guns and their Durability.	A. Rigg	1867	249
Construction, The, and Repair of Roads	G. R. Strachan	1889	17
Construction, Modern Tramway	A. W. Jones	1879	79
Construction, Modern Roadway	H. S. Copland	1878	61
Construction of Chelsea Bridge	G G. Page	1863	77
Construction of Modern Piers	J. W. Wilson	1875	29
Continental Intercommunication, English and	P. F. Nursey	1869	154
Continuous and Automatic Brakes, Hydraulic	E. D. Barker	1879	75
Continuous Brakes, Recent arrangements of	St. J. V. Day	1875	87
Continuous Railway Brakes	W. H. Fox	1872	112
,, ,, ,, ...	,, ,, ...	1873	33
Conversion of Peat into Fuel and Charcoal	C E. Hall	1876	151
Cooper's Coal-liming Process	J. A. Wanklyn	1884	167
Cornish Pumping Engine, The Use of the	A. Fraser	1864	78
Corrosion in Steam Boilers	J. H. Paul	1891	147
Cotton Press, The Accumulator	E. Matheson	1868	264
Country Mansions and Estates, Water Supply to	G. Harris	1899	231
Crushing, Dry, Machinery	S. H. Cox	1892	101
Cylinders, Equalising the Wear in Horizontal Steam	W. Schönheyder ..	1878	45
Cylinders, Friction in Steam	P. Jensen	1870	17
Cyprus, Engineering Notes on	C. J. Alford	1880	131
Darien and the Ship Canal, The Isthmus of	Dr. E. Cullen	1868	52
Deep Boring near Freistadt, Austria, by the Canadian System.	R. N. Boyd	1894	119
Deep-Sea Lighthouses, Feasibility and Construction of	C. Anderson	1883	45
Deep-water Entrances, Tidal Approaches and	J. B. Redman	1885	143
Defects of Steam Boilers and their Remedy.	A. C. Engert	1884	25
Dephosphorisation of Iron in the Puddling Furnace.	P. S. Justice	1885	169
Design, Strength, and Cost of Bridge Floors.	E. Olander	1887	27
Designing and Construction of Storage Reservoirs, The	A. Jacob	1866	225
Designs, Specifications, and Inspection of Ironwork.	H. W. Pendred	1883	87
Direct-acting Hydraulic Machinery ..	R. H. Tweddell	1877	95
Direct-acting Pumping Engines ..	P. B. Björling	1877	79
Discharging and Storing Grain	W. G. Wales	1896	149
Disinfection of the Maidstone Water Service Mains.	G. S. Woodhead and W. J. Ware	1900	49
Disposal of Sewage, The	H. Robinson	1879	197

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Distilling and Hoisting Machinery for Sea-going Vessels.	H. W. Pendred	1880	55
Distribution of Electrical Energy by Secondary Generators.	J. D. Gibbs	1885	49
Diving Apparatus	C. W. Stocker	1860	32
Dock Basins and Dry Docks, Ship Caissons for	J. J. F. Andrews	1890	189
Docks, Floating.—The Depositing Dock and the Double-power Dock.	J. Standfield	1881	81
Drainage and Water Supply to the Town of Fareham.	T. Buckham	1869	41
Drainage Construction, Notes on certain details of	G. J. G. Jensen	1901	19
Drainage of Town Houses	G. M. Lawford	1891	187
Drainage Works, Main, Acton	C. N. Lailey	1888	125
Drainage of the Fens, The	B. Latham	1862	154
Dry Crushing Machinery	S. H. Cox	1892	101
Dundee Street Improvements and Drainage of Lochee.	A. Greig	1883	113
Earth, The General Structure of	W. H. Stephenson	1858	12
Earthworks, A New Method of Setting out the Slopes of	C. J. Light	1873	216
Economics of Railway Maintenance	E. S. Crompton	1870	101
Economic Uses of Blast Furnace Slag	P. F. Nursey	1873	196
Effect of Sea Water on Portland Cement	H. Faija	1888	39
Effect of Strain on Railway Axles, and the Minimum Flexion Resistance-Point in Axles, The	T. Andrews	1895	181
Elastic Railway Wheels	V. Pendred	1864	119
Electric Light Engineering, Notes on	C. H. W. Biggs and W. W. Beaumont	1882	23
Electric Telegraph, The	W. Ansell	1857	11
Electric Telegraph Instruments	E. G. Bartholomew	1872	53
Electric Telegraphy, irrespective of Telegraphic Apparatus.	” ”	1869	55
Electric Traction, Notes on	A. H. Binyon	1900	103
Electrical Batteries	” ”	1872	77
Electrical Energy, Distribution of, by Secondary Generators.	J. D. Gibbs	1885	49
Electrical Traction, and its Financial Aspect.	S. Sellon	1892	37
Electricity, the Application of, to Hoisting Machinery.	R. Bolton	1892	79
Electricity, The application of, to the ignition of Blasting Charges.	G. G. André	1878	123
Electricity, The Lighting and Extinction of Street Gas Lamps by	St. G. Lane Fox	1878	105
Electricity, Water and Gas, Power Distribution by	E. C. de Segundo	1894	143
Electrolytic Treatment of Complex Sulphide Ores	S. O. Cowper-Coles	1899	203
Elevators, Safety Appliances for	H. W. Umney	1895	113

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Embankments, Reservoir	W. Fox	1898	23
Embankments, The Closing of Breaches in Sea and River.	R. F. Grantham	1900	21
Enclosure of Lands from the Sea, and the Construction of Sea and other banks.	E. Olander	1862	25
Engineering, Collieries and Colliery	R. N. Boyd	1893	169
Engineering Enterprise, American	A. Rigg	1885	21
Engineering Notes on Cyprus	C. J. Alford	1880	131
Engineering in India	F. C. Danvers	1868	137
Engineering of Malting	H. Stopes	1884	65
Engines, Direct-acting Pumping	P. B. Björling	1877	79
Engines for Mines, Recent Improvements in Pumping	H. Davey	1873	182
Engines for Town Water Supply, Pumping	„ „	1867	88
Engines, Gas	C. Gandon	1881	27
Engines, Hydraulic Rotative	A. Rigg	1896	89
Engines, Obscure Influences of Reciprocation in High Speed	A. Rigg	1886	83
Engines on the Rimutakai Incline, New Zealand, The Fell	R. J. Alford	1882	121
Engines, Pumping	W. T. Carrington	1859	19
Engines, Steam Fire, and the late trial at the Crystal Palace.	W. Roberts	1863	163
Engines, The Adhesion of Locomotive, and certain expedients for increasing or supplementing that Function.	V. Pendred	1865	207
Engines, Use of the Cornish Pumping	A. Fraser	1864	78
English and Continental Intercommunication.	P. F. Nursey	1869	154
English and French Compound Locomotives, Notes on.	C. Rous-Marten	1900	173
Equalising the Wear in Horizontal Steam Cylinders.	W. Schönheyder	1878	45
Examples of Railway Bridges for Branch Lines	M. A. Pollard-Urquhart	1896	117
Examples of Recent Practice in American Locomotive Engineering.	V. Pendred	1872	19
Exhaust Steam, Apparatus for Utilising the Waste Heat of	J. Atkinson	1878	167
Exhaust Steam, Treatment and Utilisation of	P. Griffith	1890	163
Exhibitions as Aids to Engineering Progress, Value of The	S. Barnett	1883	75
Experimental Researches into the Nature and Action of Steam Boilers.	T. Baldwin	1867	23
Experiments on the Strength of Materials, The Need of further	C. J. Light	1869	194
Explosion at Erith, and the Repair of the River Bank.	L. G. Moore	1864	183
Explosions, Steam Boiler	P. F. Nursey	1863	1
Explosive Compounds for Engineering Purposes.	„ „	1869	10
Explosive Compounds, Recent Improvements in	„ „	1871	108

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Explosives, High, Recent Developments	P. F. Nursey	1889	75
Extension and Permanent Set of Wrought Iron, The	C. E. Browning	1858	15
Extraction of Gold, The Chemical	P. F. Nursey	1860	42
Fareham, Drainage and Water Supply of the Town of	T. Buckham	1869	41
Feasibility and Construction of Deep-sea Lighthouses.	C. Anderson	1883	45
Fell Engines on the Rimutakai Incline, New Zealand.	R. J. Alford	1882	121
Fens, The Drainage of the	B. Latham	1862	154
Filter Presses for Sewage Sludge	J. Croll	1897	121
Filtration by Machinery	E. Perrett	1888	106
Filtration, Forced, of Water through Concrete	H. Faija	1889	107
Fire-clay Manufactures	W. H. Stevenson	1861	17
Fire Engines, Steam	W. Roberts	1863	163
Fireproof Floors	G. M. Lawford	1889	43
Floating Breakwaters	T. Cargill	1871	146
Floating Docks: The Depositing Dock and the Double-power Dock.	J. Standfield	1881	81
Floors, Fireproof	G. M. Lawford	1889	43
Flow of Water, New Formula for, in Pipes and Open Channels.	E. C. Thrupp	1887	224
Flues and Ventilation	A. H. C. Trewman	1876	91
Flues in Lancashire and similar Boilers, The Strength of	W. Martin	1882	157
Foreign Sewage Precipitation Works	A. Wollheim	1892	123
Foreshore Protection, with special reference to the Case System of Groyning	R. G. Allanson-Winn	1899	133
Forms and Construction of Channels for the Conveyance of Sewage.	J. Phillips	1874	145
Forms and Strengths of Beams, Girders and Trusses, The	R. M. Ordish	1858	13
Foundry Work, Practice of	H. R. Hooper	1888	191
Fox's Patent System of Solid-pressed Steel Waggon and Carriage Frames.	P. F. Nursey	1889	197
Friction in Steam Cylinders	P. Jensen	1870	17
Friction of the Slide Valve and its Appendages.	T. Adams	1866	6
Fuel	P. F. Nursey	1864	1
Fuel and Charcoal, The Conversion of Peat into.	C. E. Hall	1876	151
Fuel, Liquid	P. F. Tarbutt	1886	193
Furnace, The Blowpipe Flame	A. C. Engert	1884	185
Gas, Apparatus employed for Illumination with Coal	W. Sugg	1869	134
Gas Engines	C. Gandon	1881	27
Gas-Engine, Modern, Practice	S. Griffin	1889	169
Gasholder Construction	E. L. Pease	1894	95
Gas, Illumination by means of Compressed	P. F. Nursey	1881	57

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Gas Meters and Pressure Gauges	J. Willcock	1860	37
Gas, Modern Improvements in the Manufacture of Coal	R. P. Spice	1886	131
Gas Retorts, An Improved Method of Charging and Drawing	F. W. Hartley	1875	185
Gas Retorts, Charging and Drawing by Machinery.	J. Somerville	1873	138
Gas Retorts, Machine Stokers for	H. O'Connor	1891	117
Gas Station Governors, Automatic	H. O'Connor	1897	67
Gas Substitutes	V. B. Lewes	1893	141
Gas, The Manufacture of Coal	A. F. Wilson	1864	35
Gas, The Methods employed in the determination of the Commercial Value and Purity of Coal	F. W. Hartley	1869	100
Gas and Water Mains, The Prevention of Leakage in	C. M. Barker	1869	79
Gas Works at Home and Abroad, Modern	H. Gore	1868	233
Gas Works Machinery	E. A. Harman	1898	97
General Structure of the Earth, The	W. H. Stephenson	1858	12
Generation and Expansion of Steam	W. T. Carrington	1858	15
Giffard's Injector	L. Olrick	1865	280
Gold, The Chemical Extraction of	P. F. Nursey	1860	42
Government Brake Trials	T. Maude	1875	129
Governors, Marine	L. Olrick	1862	104
Governors, Sensitiveness and Isochronism in	A. Rigg	1880	73
Grain, Discharging and Storing	W. G. Wales	1896	149
Guns, The connection between the Shape of Heavy, and their Durability.	A. Rigg	1867	249
Harbour Bars: their Formation and Removal.	H. F. Knapp	1878	139
Harbours of Refuge, Breakwaters and	J. T. Kershaw	1859	31
Hauling Machinery, The new Pit and, for the San Domingos Mine in Portugal.	J. Bernays	1879	29
High Pressure Steam and Steam Engine Efficiency.	W. W. Beaumont	1888	221
Hoisting Machinery, The Application of Electricity to	R. Bolton	1892	79
Horse Haulage, the Mechanics of	T. H. Brigg	1896	21
Horse Railways and Street Tramways.	H. Gore	1873	113
House Drainage, Notes on the Proposed By-laws of the London County Council with respect to.	J. P. Barber	1897	17
Houses, Town, Drainage of	G. M. Lawford	1891	187
Hydraulic Continuous and Automatic Brakes.	E. D. Barker	1879	75
Hydraulic Experiments, the Roorkee	E. S. Bellasis	1886	41
Hydraulic Lifts	R. Carey	1893	101
Hydraulic Machinery, Direct-acting	R. H. Tweddell	1877	95

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Hydraulic Machinery for lifting Vessels in the Thames Graving Dock, The New	J. Amos	1859	17
Hydraulic Rotative Engines	A. Rigg	1896	89
Hydro-extraction, The Principles and Practice of	H. B. Ransom	1894	227
Ice-making Machinery	C. Pieper	1882	139
Ignition of Blasting Charges, The application of Electricity to	G. G. André	1878	123
Ilford, The Main Drainage of	R. G. Hetherington ..	1901	173
Illumination by means of Compressed Gas.	P. F. Nursey	1881	57
Illumination with Coal Gas, Apparatus employed for	W. Sugg	1869	134
Improved Method of Charging and Drawing Gas Retorts.	F. W. Hartley	1875	185
Improvements in Explosive Compounds, Recent	P. F. Nursey	1871	103
Improvements in Pumping-engines for Mines, Recent	H. Davey	1873	182
Improvements in Tin Dressing Machinery, Recent	S. H. Cox	1874	11
Incrustation in Marine Boilers	P. Jensen	1866	117
India, Engineering in	F. C. Danvers	1868	137
Induced *v.* Forced Draught for Marine Boilers.	W. A. Martin	1886	111
Indus, Steam Navigation on the	A. Warren	1863	139
Injector, Giffard's	L. Olrick	1865	280
Injector, The most Recent Improvements on the	J. Gresham	1867	266
Instruments, Electric Telegraph	E. G. Bartholomew ..	1872	53
Insurance, Marine	G. W. Allan	1858	14
Intercommunication, English and Continental	P. F. Nursey	1869	154
Intercommunication, Railway Train ..	S. A. Varley	1873	162
International System of Marine Course Signalling.	Capt. W. B. Barker ..	1884	47
Inundations of Marsh Land	B. Latham	1862	173
Iron Ores, The Treatment of Low-Grade, for the Smelting Furnace.	T. B. Grierson	1901	69
Iron, The Dephosphorisation of, in the Puddling Furnace.	P. S. Justice	1885	169
Iron, The Manufacture of	E. Riley	1861	59
Iron, The Relation between the Safe Load and ultimate Strength of	Z. Colburn	1863	35
Iron, The quality of, as now used ..	E. Matheson	1867	168
Iron Roofs	A. T. Walmisley ..	1881	123
Iron and Steel, Protective Metallic Coatings for.	S. O. Cowper-Coles ..	1898	139
Iron and Steel Surfaces, The Preservation and Ornamentation of	G. Bower	1883	59
Ironwork, Designs, Specifications, and Inspection of	H. W. Pendred	1883	87

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Irrigation with Town Sewage	G. King	1865	84
Irrigation Works in South Africa	J. F. Stow	1901	159
Isochronism in Governors, Sensitiveness and	A. Rigg	1880	73
Isthmus of Darien and the Ship Canal	Dr. E. Cullen	1868	52
Japan, Railway Tunnelling in	T. M. Rymer-Jones	1882	101
Joints, Single- and Double-riveted	T. Baldwin	1866	150
Land and Naval Purposes, Signalling for	F. Wise	1863	117
Lartigue Single-rail Railway, The	F. B. Behr	1886	163
Laws, Decrees and Regulations relating to Mining Operations in the old kingdom of Sardinia.	C. J. Alford	1879	106
Leakage in Gas and Water Mains, The prevention of	C. M. Barker	1869	79
Leicester Main Drainage, The	E. G. Mawbey	1893	25
Lifts, Hydraulic	R. Carey	1893	101
Light Railways	W. Lawford	1888	181
Light Railways and Tramways, Parliamentary Procedure as affecting	W. W. Beaumont and S. Sellon.	1895	33
Lighthouses, The feasibility and construction of Deep-sea	C. Anderson	1883	45
Lighting and Extinction of Street Gas-Lamps by Electricity.	St. G. Lane Fox	1878	105
Linde System, Trial of a Refrigerating Machine on the	T. B. Lightfoot	1891	39
Liquid Fuel	P. F. Tarbutt	1886	193
Lochee, Dundee Street Improvements and Drainage of	A. Greig	1883	113
Locks and Fastenings	W. P. Miles	1860	26
Locomotive Engineering, Examples of recent Practice in American	V. Pendred	1872	19
Locomotive Engines, The adhesion of	„ „	1865	207
Locomotives, English and French Compound, Notes on.	C. Rous-Marten	1900	173
Macadam for Roads, Modern Machinery for preparing	C. E. Hall	1879	51
Machine, Refrigerating, on the Linde System, Trial of	T. B. Lightfoot	1891	39
Machinery, Dry, Crushing	S. H. Cox	1892	101
Machinery, Refrigerating, on Board Ship	T. B. Lightfoot	1887	105
Machinery, Filtration by	E. Perrett	1888	106
Machinery and Utensils of a Brewery	T. Wilkins	1871	10
Machinery, Gas Works	E. A. Harman	1898	97
Machinery, Quartz Crushing	P. F. Nursey	1860	17
Machine Stokers for Gas Retorts	H. O'Connor	1891	117
Machine Tools	E. C. Amos	1899	51
Machine Tools and Appliances, application of Water Pressure to	R. H. Tweddell	1890	35
Machinery employed in laying the Atlantic Cable, The	J. Amos	1858	13

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Machinery employed in raising Water from an Artesian Well, The	W. Morris	1860	29
Machinery, Mining	E. Edwards	1859	35
Machinery, Paper-Making	R. Henderson	1900	139
Machinery, Weighing, and Automatic Apparatus in connection therewith.	W. H. Brothers	1890	55
Maidstone Water Service Mains, Disinfection of the.	G. S. Woodhead and W. J. Ware	1900	49
Main Drainage and Sewage Disposal Works, Wimbledon	W. S. Crimp	1888	73
Main Drainage of Ilford	R. G. Hetherington ..	1901	173
Main Drainage, The Leicester	E. G. Mawbey	1893	25
Main Drainage Works, Acton	C. N. Lailey	1888	125
Maintenance, Economics of Railway ..	E. S. Crompton ..	1870	101
Malting, The Engineering of	H. Stopes	1884	65
Mandalay Railway, The Shan Hill Country and the	E. W. Wagstaff	1899	21
Manufacture, Modern Coal Gas	C. C. Carpenter	1891	61
Manufacture of Coal Gas	A. F. Wilson	1864	35
Manufacture of Iron	E. Riley	1861	59
Marine Boilers, Incrustation in	P. Jensen	1866	117
Marine Boilers, Induced *v.* Forced Draught for	W. A. Martin	1886	111
Marine Course Signalling, International System of	Capt. W. B. Barker ..	1884	47
Marine Governors	L. Olrick	1862	104
Marine Insurance	G. W. Allan	1858	14
Marine Worms, Action of and Remedies for, at San Francisco.	J. Blackbourn . ..	1874	111
Marsh Lands, The Inundations of ..	B. Latham	1862	173
Mechanical Firing of Steam Boilers ..	J. W. Pearse	1877	31
Mechanical Puddling	P. F. Nursey	1874	77
Mechanical Saws	S. W. Worssam	1867	196
Mechanics of Horse Haulage	T. H. Brigg	1896	21
Metallic Bars and Tubes, The Production of, under Pressure.	P. F. Nursey	1901	45
Methods employed in the Determination of the Commercial Value and Purity of Coal Gas.	F. W. Hartley	1869	100
Milford Haven and its New Pier Works.	H. Davey	1872	89
Milling Machinery, Roller	J. H. Carter	1883	125
Mineralogy of the Island of Sardinia ..	C. J. Alford	1879	93
Mining Machinery	E. Edwards	1859	35
Mining Operations in the old kingdom of Sardinia, Laws, &c., relating to	„ „	1879	106
Modern Bronze Alloys for Engineering purposes.	P. F. Nursey	1884	127
Modern Coal Gas Manufacture	C. C. Carpenter	1891	61
Modern Gas-Engine Practice	S. Griffin	1889	169
Modern Gasworks at Home and Abroad	H. Gore	1868	233
Modern Improvements in the Manufacture of Coal Gas.	R. P. Spice	1886	131
Modern Roadway Construction	H. S. Copland	1878	61

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Modern Steel as a Structural Material	W. W. Beaumont	1880	109
Modern Systems of Generating Steam	N. J. Suckling	1874	39
Modern Tramway Construction	A. W. Jones	1879	179
Mortars and Cements	G. Robertson	1857	11
Motor Vehicles, Petroleum	J. D. Roots	1899	95
National Value of Cheap Patents	F. W. Grierson	1880	145
Navigation on the Indus, Steam	A. Warren	1863	139
Need of further Experiments on the Strength of Materials.	C. J. Light	1869	194
New Formula for the Flow of Water in Pipes and Open Channels.	E. C. Thrupp	1887	224
Notes on Cyprus, Engineering	C. J. Alford	1880	131
Notes on Electric Light Engineering	C. H. W. Biggs and W. W. Beaumont	1882	23
Notes on the Proposed By-laws of the London County Council with respect to House Drainage.	J. P. Barber	1897	17
Nunhead, Shortlands and, Railway	A. G. Drury	1892	219
Obituary		1887	265
”		1888	253
”		1889	219
”		1890	211
”		1891	215
”		1892	243
”		1893	237
”		1894	253
”		1895	269
”		1896	241
”		1897	201
”		1898	233
”		1899	259
”		1900	267
”		1901	231
Obscure Influences of Reciprocation in High-speed Engines.	A. Rigg	1886	83
Opening Bridges on the Furness Railway.	C. J. Light	1885	119
Ores, The Electrolytic Treatment of Complex Sulphide	S. O. Cowper-Coles	1899	203
Paints, The Use of, as an Engineering Material.	E. Spon	1875	69
Panama Railroad, The	Dr. E. Cullen	1868	39
Paper-Making Machinery	R. Henderson	1900	139
Paris Exhibition, Visit to the		1867	151
Parliamentary Procedure as affecting Light Railways and Tramways, Notes on	W. W. Beaumont and S. Sellon.	1895	33
Patent Laws, The	C. D. Abel	1865	25
” ” ”	W. L. Wise	1870	45
Patents, The National Value of Cheap	F. W. Grierson	1880	145
Peat, The Conversion of, into Fuel and Charcoal.	C. E. Hall	1876	151

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Peaty Water, The Action of, on a Boiler	E. Riley	1862	45
Percolation Gauges, Relative Value of	R. E. Middleton	1895	153
Permanent Way of Railways, The	C. J. Light	1859	21
Permanent Way of Railways, The	G. Bowers	1857	11
Perspective	W. Parsey	1859	26
Petroleum Motor Vehicles	J. D. Roots	1899	95
Photographic Surveying	J. B. Lee	1899	171
Photography	F. R. Moultrie	1857	12
Pick's System of Manufacturing Salt in Vacuo.	P. F. Nursey	1890	115
Piers, The Construction of Modern	J. W. Wilson, junr.	1875	29
Pier Works, Milford Haven and its New	H. Davey	1872	89
Pile-Driving	H. O'Connor	1894	71
Piles, Screw	H. P. Stephenson	1857	12
Piling and Coffer Dams	F. W. Bryant	1859	38
Pin-connected *v.* Riveted Bridges	J. H. Cunningham	1889	131
Pioneer and Portable Railways	J. Kerr	1891	89
Pipe Sewers of Croydon and the Causes of their Failure, The	J. T. Kershaw	1860	52
Pits and Hauling Machinery for the San Domingos Mines in Portugal.	J. Bernays	1879	29
Pollution of Water, and its Correction	R. E. Middleton	1897	173
Portable and Pioneer Railways	J. Kerr	1891	89
Portland Cement	H. Faija	1885	95
Portland Cement, Effect of Sea Water on	H. Faija	1888	39
Portland Cement, some Points in its Testing, Uses and Abuses.	D. B. Butler	1895	61
Portland Cement, The Effect of Admixtures of Kentish Ragstone, &c., upon	D. B. Butler	1896	179
Power Distribution by Electricity, Water and Gas.	E. C. de Segundo	1894	143
Practical Construction in the Colonies	W. G. Ferrar	1875	53
Practical Examples of Blasting, Some	P. F. Nursey	1893	201
Practice of Foundry Work	H. R. Hooper	1888	191
Preparation of Rhea Fibre for Textile Purposes, The	P. F. Nursey	1898	177
Preservation and Ornamentation of Iron and Steel Surfaces.	G. Bower	1883	59
Pressure Gauges, Gas Meters and	J. Willcock	1860	37
Prevention of Smoke	A. C. Engert	1881	101
Prevention of Leakage in Gas and Water Mains.	C. M. Barker	1869	79
Primary Batteries for Illuminating Purposes.	P. F. Nursey	1887	185
Priming of Steam Boilers	W. Major	1877	59
Principles and Practice of Hydro-extraction, The	H. B. Ransom	1894	227
Propeller, The Screw	A. Rigg	1868	202
Propellers, Screw; their Shafts and Fittings.	H. W. Pendred	1875	151
Propulsion, The Theory of Screw	M. Sefi	1870	82
Protection of Underground Water Suplies, The.	J. C. Thresh	1898	47

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Protective Metallic Coatings for Iron and Steel.	S. O. Cowper-Coles	1898	139
Puddling Furnace, The Dephosphorisation of Iron in	P. S. Justice	1885	169
Puddling, Mechanical	P. F. Nursey	1874	77
Pumping Engine, The Use of the Cornish	A. Fraser	1864	78
Pumping Engines	W. T. Carrington	1859	19
Pumping Engines, Direct-acting	P. B. Björling	1877	79
Pumping Engines for Mines, Recent Improvements in	H. Davey	1873	182
Pumping Engines for Town Water Supply.	” ”	1867	88
Pumping Machinery, The Underground, at the Erin Colliery, Westphalia.	” ”	1876	119
Pump Valves	J. Hendry	1859	25
Quality of Iron, as now used	E. Matheson	1867	168
Quartz Crushing Machinery	P. F. Nursey	1860	17
Railway Amalgamation, State Railways and	G. Spencer	1872	43
Railway Axles, The Strength of Wrought-iron	T. Andrews	1879	143
Railway Axles, The Effect of Strain on, and the Minimum Flexion-Resistance Point in Axles.	” ”	1895	181
Railway Brakes, Continuous	W. H. Fox	1872	112
” ” ”	” ”	1873	33
Railway Bridge at the Place de l'Europe	T. Cargill	1866	191
Railway Bridge over the Thames, The Charing Cross	M. Parkes	1864	166
Railway Bridges for Branch Lines, Examples of	M. A. Pollard-Urquhart	1896	117
Railway Maintenance, The Economics of	E. S. Crompton	1870	101
Railway Switches and Crossings	C. J. Light	1857	13
Railways, Street	C. L. Light	1860	56
Railways, The Permanent Way of	G. Bowers	1857	11
” ” ”	C. J. Light	1859	21
Railway, The Shortlands and Nunhead	A. G. Drury	1892	219
Railway, The Channel	P. F. Nursey	1876	17
Railway Train Intercommunication	S. A. Varley	1873	162
Railway Tunnelling in Japan	T. M. Rymer-Jones	1882	101
Railway Turntables	” ”	1858	11
Railway Wheels, Elastic	V. Pendred	1864	119
Railways, Horse, and Street Tramways	H. Gore	1873	113
Railways, Light	W. Lawford	1888	181
Railways, Portable and Pioneer	J. Kerr	1891	89
Rating of Engineering Undertakings	P. M. Faraday	1897	43
Recent Developments in High Explosives.	P. F. Nursey	1889	71
Recent Practice in Sewage Disposal	H. C. H. Shenton	1900	217
Reciprocation, Obscure Influences of, in High-speed Engines.	A. Rigg	1886	83

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Redhill Sewage Works, The	S. A. Reade	1868	168
Refrigerating Machine on the Linde System, Trial of	T. B. Lightfoot	1891	39
Refrigerating Machinery on Board Ship.	T. B. Lightfoot	1887	105
Relation between the Safe Load and ultimate Strength of Iron.	Z. Colburn	1863	35
Relative Value of Percolation Gauges	R. E. Middleton	1895	153
Renewal of Roof over Departure Platform at King's Cross Terminus, G.N.R.	R. M. Bancroft	1887	125
Repair of the River Bank, The Explosion at Erith and the	L. G. Moore	1864	183
Reservoir Embankments	W. Fox	1898	23
Reservoirs, Storage, The Designing and Construction of	A. Jacob	1866	225
Rhea Fibre for Textile Purposes, The Preparation of.	P. F. Nursey	1898	177
Rigidity, Strength and	W. E. Kochs	1865	69
River Pollution caused by Sewage Disposal.	G. B. Jerram	1886	217
River Thames, Wooden Jetties on the	J. G. Davenport	1860	24
Riveted, Pin-connected Bridges *v.*	J. H. Cunningham	1889	135
Road Bridges of Charing Cross Railway	M. Parkes	1864	143
Roads, The Construction and Repair of	G. R. Strachan	1889	17
Roadway Construction, Modern	H. S. Copland	1878	61
Roller-milling Machinery	J. H. Carter	1883	125
Rolling of Ships	W. McNaught	1876	187
Roof, Renewal of, over Departure Platform at King's Cross Terminus, G.N.R.	R. M. Bancroft	1887	125
Roofs, Arched	C. R. von Wessely	1866	36
Roofs, Iron	A. T. Walmisley	1881	123
Roorkee Hydraulic Experiments	E. S. Bellasis	1886	41
Rural Sanitation	G. W. Usill	1877	113
Safe Load and Ultimate Strength of Iron, Relation between	Z. Colburn	1863	35
Safety Appliances for Elevators	H. W. Umney	1895	113
Safety Valves for Steam Boilers, &c.	T. Baldwin	1867	23
Salt, Pick's System of Manufacturing, in Vacuo.	P. F. Nursey	1890	115
Sanitary and Industrial, Water Purification	J. W. Pearse	1878	29
Sardinia. The Mineralogy of the Island of	C. J. Alford	1879	93
Saws, Mechanical	S. W. Worssam	1867	196
Screw Piles	H. P. Stephenson	1857	12
Screw Piles in the Construction of a Wrought-iron Bridge at Verona.	J. G. Horner	1867	52
Screw Propeller, The	A. Rigg	1868	202
Screw Propellers, their Shafts and Fittings.	H. W. Pendred	1875	151
Screw Propulsion, The Theory of	M. Sefi	1870	82
Sea and other Banks, Construction of	E. Olander	1862	25
Sea Defences	R. F. Grantham	1897	143
Sea Water, Effect on Portland Cement	H. Faija	1888	39

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Secondary Generators, Distribution of Electrical Energy by	J. D. Gibbs	1885	49
Sensitiveness and Isochronism in Governors.	A. Rigg	1880	73
Sewage, Bacterial Treatment of	G. Thudichum	1898	207
Sewage Disposal	H. Robinson	1879	197
Sewage Disposal, Recent Practice in	H. C. H. Shenton	1900	217
Sewage Disposal, River Pollution caused by	G. B. Jerram	1886	217
Sewage Disposal Works, and Main Drainage, Wimbledon.	W. S. Crimp	1888	73
Sewage, Irrigation with Town	G. King	1865	84
Sewage Matter, A new System of treating	H. Olrick	1883	23
Sewage Precipitation Works, Foreign	A. Wollheim	1892	123
Sewage Question during the last Century, The	H. A. Roechling	1901	193
Sewage Sludge, Filter Presses for	J. Croll	1897	121
Sewage, The Forms and Construction of Channels for the Conveyance of	J. Phillips	1874	145
Sewage, Ultimate Purification of	G. Thudichum	1896	199
Sewage, Utilisation of	B. Latham	1866	68
Sewage Works, Redhill	S. A. Reade	1868	168
Sewerage System, The Shone Hydro-Pneumatic.	E. Ault	1887	68
Sewer Ventilation	W. S. Crimp	1890	139
Sewers, Pipe, The Cleansing and Ventilation of	B. A. Miller	1892	167
Sewers, Ventilation of	B. Latham	1871	39
Shan Hill Country and the Mandalay Railway, The	E. W. Wagstaff	1899	21
Ship Caissons for Dock Basins and Dry Docks.	J. J. F. Andrews	1890	189
Ship Canal between the Atlantic and Pacific Oceans, The Surveys for	Dr. E. Cullen	1868	15
Ship Canal, The Isthmus of Darien and the	,, ,,	1868	52
Ships, Apparatus for Measuring the Velocity of	V. Pendred	1869	215
Ships, The Rolling of	W. McNaught	1876	187
Shone Hydro-Pneumatic Sewerage System.	E. Ault	1887	68
Shortlands and Nunhead Railway	A. G. Drury	1892	219
Signalling for Land and Naval purposes	F. Wise	1863	117
Single and Double-riveted Joints	T. Baldwin	1866	150
Slag, Economic Use of Blast-furnace	P. F. Nursey	1873	196
Slide-valve, The Friction of, and its appendages.	T. Adams	1866	6
Slopes of Earthwork, A new Method of Setting-out	C. J. Light	1873	216
Small Towns and Rural Districts, Water Supply of	P. Griffith	1896	55
Smoke, Prevention of	A. C. Engert	1881	101

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Soft *v.* Hard Water for Manufacturing purposes.	J. C. Fell	1884	103
Soil, Application of Steam to the Cultivation of the	B. Latham	1868	274
Stability of Chimney Shafts	R. J. Hutton	1887	150
State Railways and Railway Amalgamation.	G. Spencer	1872	43
Steam, Apparatus for Utilising the Waste Heat of Exhaust	J. Atkinson	1878	167
Steam Boilers, Corrosion in	J. H. Paul	1891	147
Steam Boilers, The Defects of, and their Remedy.	A. C. Engert	1884	25
Steam Boiler Explosions	P. F. Nursey	1863	1
Steam Boilers, Experimental Researches into the Nature and Action of	T. Baldwin	1867	23
Steam Boilers, The Priming of	W. Major	1877	59
Steam Boilers, Mechanical Firing of	J. W. Pearse	1877	31
Steam Boilers, Water and its effect on	H. K. Bamber	1867	65
Steam Carriages	A. F. Yarrow	1862	128
Steam Cylinders, Equalising the Wear in Horizontal.	W. Schönheyder	1878	45
Steam Cylinders, Friction in	P. Jensen	1870	17
Steam Fire Engines, and the late trial at the Crystal Palace.	W. Roberts	1863	163
Steam, High Pressure, and Steam Engine Efficiency	W. W. Beaumont	1888	221
Steam, Modern Systems of Generating	N. J. Suckling	1874	39
Steam Navigation on the Indus	A. Warren	1863	139
Steam, Generation and Expansion of	W. T. Carrington	1858	15
Steam, The Utilisation of Town Refuse for generating	T. W. Baker	1894	183
Steel, Modern, as a structural Material	W. W. Beaumont	1880	109
Steel Needles, The Use of, in driving a Tunnel at King's Cross.	W. H. Holttum	1892	199
Steel Waggon and Carriage Frames, Fox's System of Solid-pressed	P. F. Nursey	1889	197
Stokers, Machine, for Gas Retorts	H. O'Connor	1891	117
Stone-sawing Machinery	H. Conradi	1876	135
Storage Reservoirs, Designing and Construction of	A. Jacob	1866	225
Street Railways	C. L. Light	1860	56
Street Subways for Large Towns	C. Mason	1895	91
Street Tramways, Horse Railways and	H. Gore	1873	113
Strength and Rigidity	W. E. Kochs	1865	69
Strength of Flues in Lancashire and similar Boilers.	W. Martin	1882	157
Strength of Materials, Need of further Experiments on the	C. J. Light	1869	194
Strength of Suspension Bridges, The	C. E. Browning	1858	11
Strength of Wrought-iron Railway Axles	T. Andrews	1879	143
Substitutes, Gas	V. B. Lewes	1893	141
Subways, Concrete, for Underground Pipes.	A. T. Allen	1901	99

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Subways for Large Towns, Street ..	C. Mason	1895	91
Sugar-making Machinery	P. F. Nursey	1865	155
Super-heating of Steam, and the various Appliances employed therein.	,, ,, ...	1861	36
Supply of Water to Towns	B. Latham	1864	199
Surface Condensers	J. Louch	1861	96
Suspension Bridges	R. M. Ordish	1857	13
Switches and Crossings, Railway ..	C. J. Light	1857	13
Tables, Circular	H. Hakewill	1865	147
Telegraph Instruments, Electric	E. G. Bartholomew ..	1872	53
Telegraph, The Electric	W. Ansell	1857	11
Telegraphy, Electric, irrespective of Telegraphic apparatus.	,, ,, ...	1869	55
Testimonial to Mr. Alfred Williams ..	.. ..	1868	161
Thames Graving Dock, The New Hydraulic Machinery for lifting Vessels in the	J. Amos	1859	17
Theory of Screw Propulsion	M. Sefi	1870	82
Tidal Approaches and Deep-water Entrances.	J. B. Redman	1885	143
Tidal Energy, Utilisation of..	A. Oates	1882	81
Timbering of Trenches and Tunnels ..	C. Turner	1871	90
Tin-dressing Machinery, Recent Improvements in	S. H. Cox	1874	11
Tools, Machine	E. C. Amos	1899	51
Town Houses, Drainage of	G. M. Lawford	1891	187
Town Refuse, The Economical Disposal of	B. D. Healey	1900	65
Town Sewage, Irrigation with	G. King	1865	84
Towns, Supply of Water to	B. Latham	1864	199
Town Water Supply, Pumping Engines for	H. Davey	1867	88
Traction, Electrical, and its Financial Aspect.	S. Sellon	1892	37
Tramway Construction, Modern	A. W. Jones	1879	179
Tramway Rolling Stock, and Steam in connection therewith.	C. C. Cramp	1874	119
Tramway and other Rails, The Cleaning of	H. Conradi	1893	47
Tramways, Cable	W. N. Colam	1885	69
Treating Sewage Matter, A new system of	H. Olrick	1883	23
Treatment and Utilisation of Exhaust Steam.	P. Griffith	1890	163
Trial of a Refrigerating Machine on the Linde System	T. B. Lightfoot	1891	39
Trussed Beams	W. Parsey	1862	52
Tube Wells	A. Le Grand	1877	133
Tube Wells for large Water Supply ..	R. Sutcliff	1877	149
Tunnelling, Railway, in Japan	T. M. Rymer-Jones ..	1882	101
Tunnels, Timbering of Trenches and ..	C. Turner	1871	90
Tunnel, The Use of Steel Needles in driving, at King's Cross.	W. H. Holttum	1892	199
Turntables, Railway	C. J. Light..	1858	11

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Ultimate Purification of Sewage	G. Thudichum	1896	199
Underground Pumping Machinery at the Erin Colliery, Westphalia.	H. Davey	1876	119
Use of Coal in Furnaces without Smoke	C. F. T. Young	1862	66
Use of Steel Needles in driving a Tunnel at King's Cross.	W. H. Holttum	1892	199
Utensils of a Brewery, Machinery and	T. Wilkins	1871	10
Utilisation of Coal Slack in the Manufacture of Coke for Smelting.	G. M. Ward	1880	33
Utilisation of Sewage	B. Latham	1866	68
Utilisation of Tidal Energy	A. Oates	1882	81
Utilisation of Town Refuse for generating Steam.	T. W. Baker	1894	183
Utilisation of Waste Mineral Substances.	E. Edwards	1861	82
Utilisation of Water Power, The	G. L. Molesworth	1858	16
Vacation Visits		1878	119
,, ,,		1879	141
,, ,,		1880	89
,, ,,		1881	121
,, ,,		1882	119
,, ,,		1883	85
,, ,,		1884	119
,, ,,		1885	113
,, ,,		1886	153
,, ,,		1887	145
,, ,,		1888	148
,, ,,		1889	131
,, ,,		1890	133
,, ,,		1891	111
,, ,,		1892	157
,, ,,		1893	133
,, ,,		1894	177
,, ,,		1895	145
,, ,,		1896	137
,, ,,		1897	115
,, ,,		1898	127
,, ,,		1899	161
,, ,,		1900	133
,, ,,		1901	137
Value of Exhibitions as Aids to Engineering Progress.	S. Barnett	1883	75
Value of Cheap Patents, The National	E. W. Grierson	1880	145
Valves, Pump	J. Hendry	1859	25
Velocity of Ships, Apparatus for Measuring the	V. Pendred	1869	215
Ventilation and Warming	W. T. Sugg	1895	235
Ventilation, Cleansing and, of Pipe Sewers.	B. A. Miller	1892	167
Ventilation, Flues and	A. H. C. Trewman	1876	91
Ventilation of Buildings	J. W. Pearse	1876	97
Ventilation of Coal Mines	G. G. André	1874	23
Ventilation of Sewers	B. Latham	1871	39
Ventilation, Sewer	W. S. Crimp	1890	139

Subject of Paper.	Author.	Transactions.	
		Year.	Page.
Verona, Screw Piles in the construction of wrought-iron Bridge at	J. G. Horner	1867	52
Visit to the Paris Exhibition	.. ..	1867	151
Waggon and Carriage Frames, Fox's Patent System of Solid-pressed Steel.	P. F. Nursey	1889	197
Waste Heat of Exhaust Steam, Apparatus for Utilising the	J. Atkinson	1878	167
Waste Mineral Substances, The Utilisation of	E. Edwards	1861	82
Water and its effects on Steam Boilers	H. K. Bamber	1867	65
Water, The Pollution of, and its Correction.	R. E. Middleton	1897	173
Water Power, The Utilisation of	G. L. Molesworth	1858	16
Water Pressure, Application of, to Machine Tools and Appliances.	R. H. Tweddell	1890	35
Water Purification, Sanitary and Industrial.	J. W. Pearse	1878	29
Water, Soft *v.* Hard, for Manufacturing purposes.	J. C. Fell	1884	103
Water Softening, by Dr. Clarke's Process	J. Glynn, Junr.	1859	29
Water Supplies, The Protection of Underground.	J. C. Thresh	1898	47
Water, Supply of, to Towns	B. Latham	1864	199
Water Supply, Preliminary Investigations for	S. A. Hollis	1901	147
Water Supply, Pumping-engines for Town	H. Davey	1867	88
Water Supply to the Town of Fareham, Drainage and	T. Buckham	1869	41
Water Supply of Small Towns and Rural Districts	P. Griffith	1896	55
Water Supply to Country Mansions and Estates	G. Harris	1899	231
Water-tube Boilers	V. Pendred	1867	109
Wear in Horizontal Steam Cylinders, Equalising the	W. Schönheyder	1878	45
Weighing Machinery and Automatic Apparatus in connection therewith.	W. H. Brothers	1890	55
Wells, Tube	A. Le Grand	1877	133
Wells, Tube, for large Water Supply	R. Sutcliff	1877	149
Wheels, Elastic Railway	V. Pendred	1864	119
Wimbledon Main Drainage and Sewage Disposal Works.	W. S. Crimp	1888	73
Wooden Jetties on the River Thames	J. G. Davenport	1860	24
Worms, The Action of Marine, and Remedies employed in the Harbour of San Francisco.	J. Blackbourn	1874	111
Wrought Iron, The Extension and Permanent Set of	C. E. Browning	1858	15

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